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REVIEW OF PANEL SURVEYS AND OTHER LONGITUDINAL TECHNIQUES

AN ANNOTATED BIBLIOGRAPHIC REVIEW

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ABSTRACT: Longitudinal panels are increasing in popularity in transport planning. Although there are a number of well-established panels in transportation, a clear case for selecting a panel as the appropriate data collection medium has not been well articulated. A major output of the First USA Conference on Panels for Transportation Planning (October 1992) was a recommendation for the development of a clear statement of the case for longitudinal data in general and panels in particular. In developing this statement, it was suggested that an annotated bibliographic review of existing empirical panels should be prepared. This paper documents the state of practice in empirical panel data collection and application. Over 60 studies using a large number of panels are reported, together with a brief statement of the advantages and disadvantages of the panel approach in contrast to a single cross-section and other longitudinal designs.

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1. INTRODUCTION

Longitudinal panels are increasingly popular in transport planning. Although there are a number of well-established panels in transportation, the case for selecting a panel as the appropriate data collection medium has not been well articulated. A major output of the First USA Conference on Panels for Transportation Planning (October 1992) was a recommendation for the development of a clear statement of the case for longitudinal data in general and panels in particular. In developing this statement, it was suggested that an annotated bibliographic review of existing empirical panels should be prepared. This paper documents the state of practice in empirical panel data collection and application. Over 60 studies using a large number of panels are reported, together with a brief statement of the advantages and disadvantages of the panel approach in contrast to a single cross-section and other longitudinal designs.

The empirical panel studies in the annotated review are from a wide range of disciplines. They include panel surveys from marketing, economics, labour market analysis, and the psychological and medical literature. These other disciplines provide insights into problems encountered with transport panels and perhaps provide some new ideas for the use of panel data in transport planning.

The literature on panel surveys falls into two broad areas:

1. Discussions of the merits of panel studies (i.e. advantages and disadvantages).
2. Descriptions of panel studies from data collection through to analysis and results.

In setting up a framework to evaluate particular panel studies, it is useful to look at the general features of panel studies as a way of highlighting their perceived advantages and disadvantages, and then to bring this knowledge into a critique of actual panel studies. This enables us to see how each study deals with, or fails to deal with, issues brought up in the general discussion of the value of panel studies.

The following section offers a brief description of the advantages and disadvantages of several longitudinal methods, with the focus on how they compare to the panel survey approach. Many of the problems arising shall be discussed in terms of the ability to control them, either via research and questionnaire design, or statistical correction at the 'pre-analysis' stage. Only

then, having gained an understanding of the literature discussing the merits of panel data, should we begin to look at the ways in which various disciplines have used panel surveys.

2. A BRIEF STATEMENT OF THE RELATIVE MERITS OF ALTERNATIVE SURVEY DESIGNS

In this section we look at the strengths and weaknesses of Panel Surveys (PS), Repeated Cross-Sections (RCS), some hybrid designs such as Rotating Panels (RP) and Split Panels (SP), and the Single Cross-Section (SCS) survey, all of which are capable of providing longitudinal data.

2.1 PANEL SURVEYS (PS)

Panel Studies have been promoted in transportation planning as one of the most valuable tools for observing and understanding the processes involved in the dynamics of travel behaviour. Kitamura (1990:402) states that

> *"...panel analysis is the most effective, sometimes the only, means through which dynamic aspects of travel behaviour can be investigated".*

The interest in panel studies

> *"...has been motivated by the advantages panel data sets offer versus repeated cross-sectional survey results with the same sample size"(Kitamura, 1989:97).*

2.1.1 Advantages of Panels

The endearing feature of a panel is its ability to capture behavioural changes over time, in a level of detail that is necessary to unravel true causality, avoiding the fallacy of ecological correlation attributable to the aggregation of information. Aggregation provides a useful framework within which to define a number of levels of information loss. The important issue is the identification of the extent to which particular aggregation rules lead to information loss which is a source of bias in making inferences about behaviour and hence behavioural response in the context of change. An example of aggregation is the assumption that sources of intra-

unit variation over time are negligible and hence can be aggregated out by treating the data as independent samples drawn from the same closed population (i.e. a repeated cross-section). At the centre of the empirical determination is the notion of state dependence, and the treatment of unobserved influences giving rise to a conditional relationship between past, present and future experience. The latter arises due to the inability of the analyst to distinguish identical individuals, one of which experienced an event in the previous period while the other did not. State dependence is a major reason for a panel.

Panel surveys measure the components of individual change and enable aggregation of data for each individual over time. PS's can also default to an SCS and be used to estimate population parameters at distinct points in time, though only if they are refreshed at each wave to remain representative of the population. They can also estimate net changes with greater accuracy than an RCS because the variance of change is reduced by a positive correlation of values between waves. Samples can be cumulated over time by combining data from several waves, providing an efficient way of collecting data on events occurring in specified time periods, the latest survey wave offering bounded recall.

Measurement of gross change is another advantage of panel data (Kitamura, 1990), in contrast to net changes in the level of a variable that an RCS is limited to measuring. Fallon (1992) gives an example of voting preferences in the recent British election, where there were 7 million people who changed their voting intention, but there was only a net swing of $1^{1}/_{4}$ million to labour from the Torries on a two party preferred basis. Kish (1985) advocates the use of panels primarily for his reason. Baanders *et al* (1984) also notes the usefulness of panel data for measuring gross turnovers.

Another important advantage of panel data is that the process of change and cause and effect relationships are much easier to establish in contrast to an RCS or SCS specification. The researcher can directly observe both changes in contributing factors and changes in behaviour. Panel surveys also have the ability to pick up response lags, non-optimal experimentation, experience effects and other intertemporal effects which are most meaningful at the level of the behavioural unit. For this reason, some issues such as process information acquisition, experimentation and learning, and behavioural changeover can only be studied by using panel surveys (Kitamura, 1989). For example, panel data enables the tracking of the evolution of the market place for particular goods and brands (Rostand and Finaz, 1983).

Hensher (1985) notes that a panel is an appropriate instrument if intra-unit effects have a significant effect on inter-temporal stability. If inter-unit effects are the only significant influences, then an RCS is satisfactory.

Forecasting is an area where panel data has some attractive properties. Forecasting changes over time using a single cross-section, for example, is based on differences in behaviour across individuals at one point in time. This maintained assumption can only hold if behaviour is contemporaneous. Logic and a number of studies suggest otherwise. Hsaio (1986) notes in a similar vein that panel data provides a larger number of data points, increasing the degrees of freedom and reducing collinearity among explanatory variables, thus improving the efficiency of econometric estimates. Kitamura states that:

> *"Repeated observations of the same respondents implies that unobserved contributing factors are well controlled, facilitating more precise measurement of behavioural changes. It also reduces sampling errors, leading to reduced sample size requirements compared with repeated cross-sectional surveys."(Kitamura, 1990:402)*

Meurs *et al* (1989) investigated the advantages of panel data over RCS data for measuring net change. They conclude that sampling errors are minimised by using panel data because there is correlation between the same variable measured at different points in time, in contrast to zero correlation for a cross-sectional survey (Duncan and Kalton, 1985). A final, and perhaps arguable, advantage of a panel is that reinterview may be less expensive than fresh interviews for each wave because the respondents are now familiar with the survey and may be able to be interviewed by phone rather than personally interviewed at home.

2.1.2   Disadvantages of Panels

Panel surveys can be problematic if nonresponse bias created by sample **attrition** between waves of the survey is not properly handled. Nonresponse can be systematic or random (Hensher 1987). Anashensel *et al* (1989) for example found that attrition bias exerted a greater impact on external validity than the internal validity of panel data in an examination of Mexican American female adolescent participation in a panel survey. Where attrition is systematic rather than random, the sample is biased. Kitamura (1990), amongst others, documents similar findings. Ridder (1990) argues that the advantages of panel data *can only be enjoyed under conditions that are seldomly satisfied in the real world*. Andrisani (1980) is of a similar mind, believing that the inherent advantages of panel data may be lost because of the over-riding disadvantage of bias related to attrition.

The most common approach to alleviate this problem is the use of some statistical compensation procedure. This can involve weighting the responses of those who have been most difficult to gain a response from; the assumption being that these people are more like the nonrespondents than the rest of the sample (Anashensel, 1989). Another technique is to follow

up some nonrespondents and weight their answers (Abeles and Wise, 1980). Hensher (1989), amongst others, has developed econometric procedures for correcting for systematic attrition.

The use of such techniques can be minimised however. Part of the solution, as suggested by Hensher (1987), van de Pol (1987) and Goulias *et al* (1990) is that survey design and implementation be carried out in such a way as to maximise response. Such techniques include regular reminder calls, concerted tracing efforts, questionnaire updating and good survey administration.

Another major set of problems is panel **stagnation** and the related issue of panel **conditioning**. Stagnation refers to the problem of a panel selected at one point in time not remaining representative of a changing population. There are several possible solutions. The most logical is panel updating. This idea involves systematic refreshment with immigrants to the target population so as to keep the sample representative. Baanders *et al* (1984) note that replacement of nonrespondents by matching has often been used, but this does not solve the stagnation problem because the characteristics of the sample are artificially kept stable over time. Updating methods may not capture the information gained by a rotating or split panel (see below), but they do maintain the integrity of the panel better than other known methods to preserve the meaning of sample comparisons across time. Refreshment strategies do however increase the sampling effort required for panel surveys in contrast to other longitudinal approaches.

Panel conditioning and fatigue are related problems which occur with multiple wave panels. Conditioning refers to biases which may result from respondents being affected in some way by participation in the survey. For example, it may make them more aware of the issues involved, especially if the aim of the survey is known to them. These problems can be addressed to a limited degree by panel refreshment, but can only be effectively overcome by using a split or rotating panel design (Duncan and Kalton, 1985). Fatigue occurs when the quality and quantity of responses begin to decline because of boredom and related phenomena. A solution used in many studies (eg. Murikami, 1992) is to limit the length of the reporting period for each wave.

Panel data can be configured in continuous time and/or discrete time. A panel has a predefined number of re-contact points in time, typically equally spaced, at which each unit of observation is required to provide information. This information can reflect the continuous nature of behaviour over time (i.e. events) or provide repeated 'snapshots' of behaviour at the time of recontact (i.e. states). Event profiles in continuous time are extremely rich sources of data enabling identification of the precise timing of change, which may not be the same as the

comparison of states associated with each of the recontact points. Indeed without a careful design of a temporal element in all the panel data (especially where the spacing between re-interview is quite long), one runs the risk of misrepresenting the dynamic linkages between causes and effects, and indeed exposes predictions to the dilemma of "the right prediction at the wrong time" (Hensher and Raimond 1992). Event data provides richer information about the process of change than does the observation of the state. Events can account for not only sequence but timing and duration, which are also important in seeking out causal ordering.

2.2   REPEATED CROSS-SECTIONS (RCS)

An RCS can provide estimates of population parameters at distinct points in time, and enable comparisons within population groups (i.e. cohorts) over time of net changes. Gross changes over time associated with each sampled member of the population cannot be identified. Although one can collect data on the frequency and timing of events in a specified time period, it may be subject to telescoping since there is no previous interview to bound the discussion.

One consequence of adopting a repeated cross-section is the need to define relatively homogeneous groupings (i.e. cohorts) of observations at each point in time so that comparisons over time can be undertaken. If cohort effects are a dominating feature of behavioural change, then a repeated cross-section is appropriate; the challenge is to establish homogeneous behavioural segments, which may or may not be unique for each behavioural application. Another example of aggregation is the assumption of stability over time in the parameter set associated with an a priori causal ordering. Where a maintained assumption is imposed on a behavioural analysis which is not rooted in a previously testable assumption, the establishment of causal order in a single cross-section may be empirically tenuous.

A series of repeated cross-sections avoids some of the complications of designs which include the same individuals in more than one round of data collection. These include (i) biases associated with panel conditioning where members of a panel become more aware of the survey topic and objectives, thus influencing their behaviour and response to the questionnaires; (ii) panel attrition where panel members drop out because of lack of interest or apathy (it has been argued that in many cases, this attrition is systematic rather than random (eg. Anashensel *et al*, 1989)); (iii) time and money spent in maintaining high response rates in subsequent waves or using statistical techniques to limit the effects of attrition bias; and (iv) the risk of stagnation due to an ability to accommodate changes in the target population.

In contrast however, an RCS cannot measure the components of individual change (gross change, average change and instability of change for each individual), it is unable to aggregate

data for individuals over time, and is rather poor at collecting data on events occurring in specified time periods because of the inability to offer bounded recall.

2.3   HYBRID SURVEY DESIGNS

Hybrid data designs such as a split panel combine a panel, a rotating panel and/or a repeated cross-section. A fully rotating panel limits the number of waves in which a sampled observation remains in the panel, reducing the information content of the data over time at the unit level. Rotation when combined with a panel as a split panel data configuration however has the advantage of enabling an assessment of sources of possible bias such as conditioning, attrition and loss of representation. In contrast to a single cross-section, estimates of net changes over time are available when both types of data are pooled, and gross changes are identifiable from the panel sub-sample.

2.3.1   Rotating Panel Surveys (RPS)

RPS's are commonly used in consumer research as a mechanism for maintaining an acceptable sample size as well as minimising potential bias due to nonresponse and panel conditioning and stagnation. Rotation is designed to preserve sample representativeness of the target population. Typically a sampled individual is not in the panel for a sufficient number of waves to be able to capture enough information to measure components of individual gross change. A rotated panel preserves all the main advantages of an RCS, but has additional strengths provided by the panel configuration. In particular, in contrast to an RCS, an RPS has the advantage that it will generally give more precise estimates at a point in time, enriching the comparison of mean parameter estimates over time. Rotating panels are also better at measuring the frequency and timing of events occurring in a given time period than an RCS because the discussion can be bounded by a previous interview (Duncan and Kalton, 1985). An RPS is generally not as useful as an RCS for cumulating samples over time, but it is more useful than a panel survey in that sample refreshment is much more systematic.

2.3.2 Split Panel Surveys (SPS)

Kish (1985) advocates split panel designs as the preferred longitudinal design for the majority of survey problems. The idea is to run a panel and a non-overlapping cross-section sample concurrently. Partial overlaps for current estimates are provided, with the combination providing the best estimate of net changes. It also incorporates the other benefits of panel surveys and the large sample size of cross-sectional surveys.

Within the panel partition of the design, components of individual change and aggregation of data for individuals over time can be handled. Population parameters can be estimated at

distinct points in time for the non-panel section, as well as for the panel section if a mechanism for taking into account population change is used. Net changes can be identified with greater accuracy than via an RCS because the variance of change is reduced by the positive correlation of values between panel waves.

The RCS or rotating component can be used to pick up new entrants to the population, providing a check on biases from panel conditioning and respondent losses and stagnation. Having an RCS permanently overlap the panel aids in the estimation of net change between any two waves, enriching the net change between two specified waves associated with a rotating panel. The panel component is also useful in providing a bounding when measuring the frequency and timing of events.

The main disadvantage of this method is the cost and effort involved. To adequately cope with all data requirements, two separate surveys must be conducted at the same time. For some purposes, simpler designs may provide equally good results, while for other applications, this design may be seen as overkill. On balance, however, this technique can combine the best features of all the other techniques, but without the burden of their major weaknesses.

2.4   SINGLE CROSS-SECTIONS (SCS)

The ultimate degree of aggregation occurs when we adopt a single-cross section (SCS) strategy. Implicit in this strategy is the idea of a 'myopic' reduced-form solution to a complex structural hypothesis of behavioural response, which reduces to a set of time-invariant parameters and cross-time parameter equalities on any lagged relationships in the structural equations. The inability of a single cross-section to handle state dependence is suggested as one reason why an SCS model tends to over-predict (Chamberlain 1978). The extent to which these strong maintained assumptions make any difference to the behavioural outcome is an empirical issue, dependent to a large extent on the objectives of the application.

An SCS is primarily designed to provide estimates of population parameters at a distinct point in time. Retrospective data however can be collected on the frequency and timing of events in a specified time period, provided that the events can be reliably recalled. Peters (1988) suggests that retrospective panels derived from an SCS survey are of value where the interest is on well-defined lifecycle events. Maddala (1987) also argues that if recall is reliable for lifecycle changes and long term decisions, then there is no need for a longitudinal survey procedure.

An SCS is relatively inexpensive and fast to administer, and is generally easier to fund than a survey which needs some long term funding commitment. It is often suggested that a longitudinal design should be promoted incrementally to funding agencies as a series of SCS's, with each justified sequentially. With the exception of retrospective panel designs, an SCS cannot provide any measure of change over time, or be used to cumulate samples over time.

3.   COMMENTARY AND CONCLUSIONS

All forms of longitudinal data are useful where the importance of an attribute of choice changes over time as a result of the *level* of the attribute at a particular point in time. For example, modal choice studies have shown that for peak travel, travel time and reliability are important; whereas for off-peak travel, frequency (i.e. headway) in public transport, comfort and security are important. The absence of frequency in peak mode choice is due to the presence of high levels of service frequency. Longitudinal studies enable identification of the impact of service change on subsequent determinants of mode choice.

The vast majority of longitudinal (panel in particular) studies undertaken in recent years have deficiencies. The most notable weaknesses are linked to sample selection, the absence of control of nonresponse bias, attrition, stagnation, and conditioning. The longitudinal strategy is also questionable in some studies. Data that could have been collected retrospectively in a one-off single cross-section, for example, was collected using a panel design. Time series information that is available from company records has been asked of people, leading to more bias than necessary. Only a few of the larger studies, which had the budget to control bias, seriously built compensators into the design. It was often left to the pre-analysis stage to even begin thinking about bias. A split panel, or a control group is desirable as a means of monitoring and allowing for the nature and level of biases that may exist. There is a lot of scope for improving the longitudinal data collection process both in terms of data quality and efficiency of collection. The annotated review summarised below provides a useful reference point. A wide range of longitudinal studies (mostly panel studies) are summarised in tabular form. Each study is described in brief, and comments provided in terms of the study purpose, data requirements, control of bias and possible design faults.

CRITIQUE OF A SELECTION OF PANEL STUDIES

(In Tabular Form)

Author	Study	Purpose	Design	Comments on Design	Control of Bias
Bohman, M. and Sigvardsson, S. (1985)	A Prospective Longitudinal Study of Adoption	To work out practical models for prediction and prevention of mental disorders and social maladjustment. This is done by looking at the social effects of adoption and fostering on the maladjustment among children with a negative social heritage.	Panel of children born after unwanted pregnancies and registered for adoptive placement at the time of their birth. The cohorts have been surveyed at ages 11, 15, 18 (for males) and 22 years. Most of the data is from second hand sources such as the children's teachers, doctors, etc. The survey is of 624 children born 1956-1957 in Stockholm, Sweden.	A panel survey appears to be the only way to obtain data on the psychological progress of adopted/fostered children. The survey waves are possibly too infrequent for this survey topic, because a lot can happen in the development of a child in three or four years. The survey results can't be claimed to be transferable because the survey was not random and only dealt with children born at approximately the same time and place.	It is especially difficult to have controls when dealing with rare groups in the population. This study had a control group of children born at the same time, but attrition levels in both groups were high, with those who stayed till the end included in the analysis. Other than having a control group, there were no reported controls of bias.
Bolton, R.N. and Drew, J.H. (1991)	GTE Telephone Service Longitudinal Study	Aims to determine the important factors influencing consumer attitudes to service changes through time.	A three wave telephone panel survey of customers using a multiple test and multiple control group design. Waves were 6 months prior to an upgrade, 1 month after, and 6 months after.(56% of the sample completed all three waves - 120 people). A model is then estimated	Longitudinal data is required since it is necessary to identify of gross attitude changes rather than net changes to understand if service level changes have any impact. Previous cross-sectional studies in the area found stability in opinion, but the turnover in this study allowed the researchers to see a lot of gross changes.	There is scant mention of any attempts to correct the sample for attrition biases or to correct the sample to make it representative of the population. The sample itself may be too small to draw any strong conclusions from.
Börsch-Supan, A. (1987)	Panel Study of Income Dynamics	To study the influence of education on labour and geographic mobility.	Panel survey (subsample) of 736 individuals observed from 1968 to 1982 on a yearly basis. Sample is of heads of households who remained in a job for the 15 year period.	Longitudinal data is necessary for following the changes of individuals over time. This study noted that education strongly affected future labour and geographic mobility, with high education inhibiting labour mobility while increasing geographic mobility. It seems, however, that these are important lifecycle changes which could probably have been recalled by respondents in a SCS.	Reliant on PSID data being controlled for bias, as no controls were mentioned in the paper.

Author	Study	Purpose	Design	Comments on Design	Control of Bias
Börsch-Supan, A. (1990)	Panel Study of Income Dynamics	Looking at a subsection of the data, the aim is to identify the various economic and demographic mechanisms underlying household choice behaviour. In particular, to look at the dynamics of mobility and housing consumption adjustment	Panel survey of 880 families (subsample of larger survey) in Michigan, including five waves from 1977 to 1981. A (conditional fixed effects) multinomial logit model is used.	Again, there is some doubt as to whether a SCS or RCS could not have achieved the same result. Housing consumption is another of those important lifecycle decisions that is made very infrequently and is easy to recall. It is true that a panel survey offers the ability to distinguish dynamic effects from selection effects that are due to time-invariant household characteristics, and the intertemporal linkages between individual consumption decisions can be discerned, but it is questionable whether these advantages of panel data outweigh the biases inherent in the process of panel data collection.	Many checks on internal bias. Presumably the PSID data has already been corrected for non-response and other biases.
Brandstädter, J. and Baltes-Götz, B. (1990)	Personal self-regulation of development in adulthood project	The study focuses on patterns of age-related change in development-related control beliefs, and the relationship of these control beliefs to the individuals emotional appraisal of his or her developmental achievements and prospects. It also looks at accommodative readjustments in developmental goals and their relationship to depression, and at age-related shifts in strategies of coping and control.	Three waves of questionnaire panel data from 1983, 1985 and 1987 of 1228 participants (married couples) in south western Germany. The data was split into 5 birth cohorts for cross-sequential comparisons.	Longitudinal data is necessary to observe temporal changes in goals and perceptions of individuals. This panel is quite short though. A longer panel may have addressed the study goals a little better.	The panel was recruited, not randomly sampled, meaning there is potential for selection bias. It is stated, somewhat vaguely, that the sample is "fairly representative of the general population"(p 199). It is also stated that no systematic dropout effect was observed on the central variables considered in the study, but this is not corroborated by any evidence.

Author	Study	Purpose	Design	Comments on Design	Control of Bias
Bray, D.W. and Howard, A. (1983)	The Management Progress Study	To provide Bell System with an idea of how managers develop and respond to lifecycle and job position changes.	A group of new managers in 1956 were followed through their career with annual interviews, not just about their position, but about their perceptions and feeling at and around the time of the interview. In addition, the participants performance in the job was reported by a colleague. Medical data is also part of the study, but is collected less frequently. The managers are being followed to their retirement. All participants are white males.	A panel study is probably the only way to collect this attitudinal/perceptual information. The major problem appears to be that the panel does not remain representative of the current group of new managers, many of whom may not be white males. A split panel design may alleviate this problem to a small degree by comparing the characteristics of a cross-section of current managers with those in the panel to obtain some indication of bias. Panel refreshment, or a continuous panel, with new entries each year, would also help maintain the representativeness of the panel. Bell System began a new panel in 1977 called the Management Continuity Study to have a look at the current generation of managers.	Panel conditioning and stagnation are definite problems with this study, but because it is an intra-company study, there is no attrition problem.
Clarke, M. and Jephcott, J. (1982)	AGB Home Audit panel survey of fuel usage	To use panel research techniques in load forecasting and energy marketing for the UK Electricity Council. Specifically, aims are to study seasonal variation and trends over time for appliance usage and understand fuel use habits.	A diary is kept by respondents for four weeks in summer and winter, detailing their use of household appliances. In 1981, the sample consisted of a subsample of 477 of the AGB Audit panel, since the ownership of appliances is known for this whole group. Recruitment of panel members occurred with small monetary incentives. Each year a new panel is recruited.	The panel is very short in duration, making it flexible, but possibly adversely affecting the reliability of results. The panel is also far from a random sample, so selection bias is almost certain. For its stated purposes though, it is a quick and easy snap-shot of energy usage. A panel is necessary to compare individual fuel usage over time and in different seasons, but perhaps a refreshed panel continuing from year to year would be more appropriate than a series of short panels.	The short panels do have the potential to control for changes in population composition over time, but since the panel in this case is recruited from those in another panel, this possible advantage is lost. As already stated, the panel is subject to selectivity bias. Between wave attrition bias is minimised by the short duration of the panel, but within wave attrition is quite high because of the length of each reporting period.

Author	Study	Purpose	Design	Comments on Design	Control of Bias
Costa, P.T. *et al* **(1983)**	Baltimore Longitudinal Study of Aging	The general aim is to examine the stability of personality in adulthood.	An updated panel running from 1958 to present which interviews volunteers every one to two years, including regular medical, cognitive and psychological testing. From an initial pool of male scientists, there has been continuous recruitment (females added from 1977) with an attempt to keep the numbers born in each decade to similar levels.	A panel survey seems to be necessary for such a study because individual changes over time are required, and these changes are not of a nature that is easily recalled. Continuous recruitment of new panel members make the sample more representative of the target population representative than when it first began, but it is still subject to a great deal of selection bias. It would have been more appropriate to randomly sample the population, and then randomly update.	Attrition bias is minimised by recruiting respondents interested in participating in the survey for scientific or personal interest reasons. However, this recruitment leaves the sample open to criticism for not being representative of the population as a whole, thus invalidating the universality of any findings. Continuous updating does overcome the problem of sample stagnation however.
Cunningham, W.R. and Owens, W.A. (1983)	The Iowa State Study of Intellectual Development in Adulthood	The purpose of this study is to examine the stability of intellectual functioning through adulthood.	A panel study was used in which male college freshmen originally tested with the 'Army Alpha' test in 1919 were retested in 1950 and 1961, and for the few surviving members, again in 1976. Principal components analysis and multiple-factor analysis studies have been carried out on the data.	A panel study appears to be the ideal design for following the development of intellect through a person's life. An RCS (as are often used for this purpose) cannot discern the dynamics of individual change, so its results could be misleading. Rather than recruit the sample, it would have been more appropriate to use a random sample. No effort was made to make the sample representative of the population (ie only males in college were used), but this is probably a reflection of the era in which the study began.	Both attrition and stagnation were important biasing factors in this study, as was the selection process. However, the author is not to blame as the study began over 70 years ago when a lot less was known about research design, and he is just reporting on the findings of others who have not felt the need to use correction techniques for any of the biases.

Author	Study	Purpose	Design	Comments on Design	Control of Bias
Davies, R. and Crouchley, R. (1985)	Gender effects in voting behaviour	The aim is to determine why men and women vote the way they do (women tend to lean more to the conservative side of politics).	A panel of 354 voters was followed through the two 1974 and the 1979 British general elections. In addition, cross-sectional data were collected for each election. This is a split panel design. Cross-sectional and longitudinal models are developed to explain voting choice conditional upon previous vote.(The approaches produced dramatically different results)	The analysis used highlights the inappropriateness of cross-sectional data to explain such a dynamic process. The panel data is much better at explaining gender effects on voting behaviour because the model allows for more complex dependencies upon the independents variables. However, a SCS (retrospective recall) design should be able to provide the longitudinal data necessary for such an analysis without the cost of conducting a panel study because voting is an infrequent and easily remembered occurrence.	Many data problems in the panel data were solved by ignoring a large proportion of the data which was suspect. However, this left the sample size a little inadequate for reliable modelling. Some potential corrections available because of the split panel nature of the design were not adopted. Both attrition and stagnation did not appear to be corrected, but the original data set may have been.
Dix, M.C. (1985)	Banbury Dwelling-Based Panel Survey Exercise	The aim was primarily to demonstrate a little used dwelling-based panel data collection technique. Its usefulness for capturing medium term dynamics of change was also assessed.	A dwelling-based panel design was used where the same dwellings, not necessarily the same people, were surveyed in two different waves. A percentage of former residents who had migrated were also traced to give some idea of patterns of migration.	A novel approach to panel data collection, and one which local authorities may find interesting and useful. It enables them to keep track of changes in both the residents who stay, and get some ideas of the types of migration flows that are occurring. This study was just a demonstration of the method, and as such should not be critiqued in the manner of the other studies.	The study recognised the need to update the dwelling sample over time if changes in dwellings occurred in the study area. There are some problems with this design, but it does have the advantage of having an automatic mechanism for updating the sample.

Author	Study	Purpose	Design	Comments on Design	Control of Bias
Dunn, R. *et al* **(1983)**	Cardiff Consumer Panel	Investigation of the empirical assumptions of the NDB model of consumer purchasing behaviour in the context of purchasing at individual stores	The panel obtained continuous records on all aspects of daily food and grocery shopping for 454 households over a 24 week period in 1982, including the name and location of each store and the mode of transport to the store. Recruitment was a random stratified sample.	An effective use of panel data since individual data makes it's locational component superior to other data sources, thus being able to test the aggregate assumptions of the NDB model at the disaggregate level. Perhaps this could be used on some transport models.	Considerable care was devoted to panel recruitment, panel control, panel remuneration and fieldworker control in order to minimise attrition. Sub-contracted the transfer of the coded diary onto computer tapes to a specialised computing firm who conducted more than 30 tests for consistency, range and logic. There were no statistical corrections for lack of representativeness of the sample because of non-response bias, but the panel is short enough to avoid stagnation problems.
Dynarski, M and Sheffrin, S.M. (1985)	Panel Study of Income Dynamics	Discussion of the role of transitory income in the housing purchase decision	Data from the PSID for the years 1969-1975 was used. This data consists of 5,000 American families randomly selected to be representative of the total population (the same households, and split-offs of these households have been re-interviewed yearly).	A longitudinal data set is necessary to measure the adjustment decisions given changes in transitory income. Again, perhaps more frequent and longer running panel waves would have been more appropriate to view changes throughout the 'business cycle'	There is little mention of corrections for attrition bias or other bias other than those that were part of the data collection process of the PSID. These were concerted efforts at tracing and maintaining sample representativeness.
Fallon, I. (1992)	Sunday Times/Mori Panel	Aim was to look at gross changes in voting patterns of British voters leading up to the 1992 election.	A panel with wave periods of one week was used, though the sample size is not reported.	A panel is extremely useful in this case as it offers a much richer view of what is going on. While other polls showed small percentage net changes in voting intentions, this poll showed the massive turnovers in opinion that were occurring within these small net changes.	Being a newspaper article, there is no discussion of sampling, attrition, non-response or the like.

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Farrington, D.P. (1988)	The Cambridge Study in Delinquent Development	The aim was to forward the research in the area of developing a causal theory of offending. In this case it investigated the development of juvenile delinquency and adult crime	A prospective longitudinal survey of 411 males who were first contacted at age 8 or 9 in 1961-2. They all lived in the same area of London and were white working class British. They have been interviewed at ages 8, 10 and 14 by a psychologist or social worker	Longitudinal data is required for a study looking at individual change, though in this case, perhaps the wave length could have been a little shorter to provide more reliable causal inferences.	It was recognised that the sample was deficient because it was not randomly drawn, but the sample was matched by socio-economic status. No bias corrections were mentioned.
Fogelman, K. (1985)	The National Child Development Study	The study had six investigative aims: change and continuity of characteristics; the relationship between early experiences and later outcomes; the relationships between change in circumstance and outcomes; changes in relationships; allowing for inputs; changes in background and changes in income.	In 1958, all the babies born in England, Scotland and Wales from 3-9 March were studied by means of a questionnaire completed by the attending midwife and an interview with the mother. It was decided to follow-up this sample (originally collected for a different purpose) at ages 7, 11 and 16. At each stage parents and schools were interviewed and the children underwent medical examination. At 11 and 16, the children filled in their own questionnaire	Longitudinal data is required for such a study, and a panel design seems appropriate. A split panel however, may have been more appropriate as the panel was limited to one generation and one area. The use of a control group, some representative cross-sections, and some panel updating to see if the causes of offending change from generation to generation may have been useful	Sample attrition was noted as a possible source of bias, but because the attrition rate was not high, few, if any, corrections seem to have been implemented. Bias in this study is discussed in Goldstein (1976).
Gaiha, R. (1988)	National Council of Applied Economic Research Additional Rural Income Survey	Aimed to explore income mobility among the rural poor in India.	A three wave panel of 4118 rural households for the year's 1968-69, 1969-70, and 1970-1971.	A panel survey design is effective when examining income mobility. The sample does appear to be very small considering the size of India's rural population, and no mention is given of the sampling techniques.	Estimates are made of sampling error for various sources of income. There is no other way to test the accuracy of income estimates in India except to compare with estimates made by others.

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Gath, A. (1985)	Down's Syndrome in the First Nine Years	A longitudinal study was undertaken in order to establish some causal relationships between age and intelligence, and background and intelligence.	All the children with Down's Syndrome born in one administrative region of the National Health Service between January 1, 1970 and December 31, 1971 were eligible, and 40 were born. Several died soon after birth. 31 children ended up living at home with a family, and these formed the sample. A matched control group was also used. The two groups were visited 6 times over the first 2 years, then again nine years later.	A panel design is a novel design for this type of work, but is useful for establishing some sort of causal relationship. In this case, measurement of intelligence at an early age was essential to compare life expectancy and intelligence at a later age. A cross-sectional design could not have achieved this. The control group also added some reliability to the results. However, there was no updating of the panel, so stagnation could be a factor if the nature of responses are changing along with changing societal values.	Of those who were still alive, all but two of the sample were successfully traced, meaning attrition bias was not great. The only real attrition bias was due to death, and that was one of the study interests. In such a study, other usual problems such as conditioning are not really a factor. Perhaps more waves, and of greater frequency may have been more valuable in gaining explanation.
Gilbert, C.C.M. (1992)	NDB-Autofacts panel survey of gasoline usage	Attempts to better capture the dynamics of automobile ownership decisions than previous discrete choice panels.	A six and a half year panel from 1978-1984 of almost 7500 households is used. They responded to a monthly mail in diary. Rather than being applied to a discrete choice model, it is applied to duration models.	Duration models run into problems with left and right censoring (ie either a car ownership spell was already underway when observations began or it had not ended when observations ceased). Duration, or hazard models can statistically control for these problems but does this obviate the advantages of the method? It is an interesting use of what the paper terms "micro panel data", and with the decision process being followed so closely, perhaps panel rather than retrospective data is necessary or at least desirable.	Panellists lost to attrition were replaced by matching, meaning stagnation of the characteristics of panellists through time occurred. Some socio-demographic groups were also under-represented. The frequency with which the panel waves occurred suggests that panel fatigue may have occurred.
Giuliano, G. and Golob, T.F. (1990)	Honolulu Staggered Work Hours Demonstration Project	The principle aims were to determine the time savings or losses for those who staggered their work hours and those who didn't, and to explain how travel time impacts of the project were distributed among commuters with different trip lengths, routes, and departure and arrival times.	The panel survey elicited commuting experiences of approximately 2000 downtown employees on each of four days, two weeks apart, for two days before and two days after the demonstration project. The sample was divided into those who staggered their work hours and those who did not. Because of the short panel duration, simple paired t-tests were used for analysis.	Given the nature of the project, where systematic effects on traffic were likely to be very small, the need to filter as many sources of random error as possible may be reason enough to use a panel instead of some cross-sectional design. External dynamic factors such as changes in employment conditions, growth in traffic congestion etc are thus controlled for, making the method worthwhile	The short term nature of the panel minimised any attrition errors, and for the same reason, stagnation and fatigue were also not a problem. Short panel length leads to validity problems, but traditional methods of analysis were not used so as to minimise this sort of problem.

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Giuliano, G. and Wachs, M. (1992)	An Employer Panel for Evaluating the Effectiveness of Trip Reduction Incentives	Measure the effectiveness of a trip reduction program.	243 worksites are surveyed over two years to analyse their progress towards ridesharing goals. The data is a government database on characteristics of employment sites.	While the panel data source – governments records – seem quite reliable, the sample is biased in favour of large employment sites because this is where ridesharing regulations were initially targeted. Longitudinal data is very valuable to observe the dynamics of individual site changes.	Other than the fact that the sample is biased towards larger sites, there is also the problem of lack of control over the recording of changes – this is presumably done by someone at the worksite.
Golob , T.F. (1988)	The Dutch National Mobility Panel	To analyse causal relationships between income, car ownership and mobility using latent structural equation modelling	Three waves (spring 1984,5 and 6), corresponding to waves 1, 3 and 5 of the panel are used. 620 households whose composition did not change over the period are used. The four variables used are income, car ownership, trips by car, and trips by bus. Use of structural equation modelling.	The results obtained do not seem to point to anything new or unexpected. They are obvious logically, and could have been arrived at in a much simpler fashion. Notwithstanding, the data requirements of the study, particularly those related to mobility, would be difficult to obtain by any other form of data collection.	As per the Dutch Mobility Panel.
Golob, T.F. (1989)	Dutch National Mobility Panel	Aims to model the causal relationship, at the household level, among income, car ownership, and trip generation by mode.	Data from waves 1, 3 and 5 (March 1984, 1985, and 1986) of the Dutch Mobility Panel are used.	The nature of the data which needs to be collected is such that a panel longitudinal design seems necessary. It would be virtually impossible to remember each trip and mode types for any given week, so a retrospective survey would be inappropriate. Longitudinal data is required when looking at causal relationships over time.	The sample has been weighted to conform with the Netherlands population (Meurs and van Wissen (1987)) and several other techniques have been used to correct bias: Golob and Meurs (1986), to correct for respondent fatigue over the seven day diary; and Kitamura and Bovy (1987) weight personal characteristics to account for the original non-random sampling and for panel attrition.

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Golob, T.F. and van Wissen, L (1989)	Dutch National Mobility Panel	Aimed to develop a dynamic simultaneous equation model of car ownership and travel distances by mode as a function of income.	A pooled wave-pair sample is used for data collected in March of 1984,5,6, and 7 of the Dutch Mobility Panel. The variables are defined at two points in time for all persons in an adjacent pair of panel waves, one year apart, giving a sample of 7,238 person-wave pairs. This method assumes that the same causal phenomena operate in each pair of adjacent waves.	The data is used in such a way as to make it cross-sectional rather than panel data, thus decreasing the opportunities to develop a truly dynamic model. Dynamic effects that are available are limited to one year's duration, which makes the model quite weak. In addition, the data collected has all the problems of panel data without any of the compensating factors, making it seem to be an inappropriate way of using panel data. Cross-sectional studies should have sufficed given the way the study was carried out, but it is questionable whether cross-sectional data is appropriate given the study objectives.	Bias correction consists of those methods described in Golob *et al* (1985) and Meurs and van Wissen (1987).
Golob, T.F., van Wissen, L. and Meurs, H. (1986)	Dutch National Mobility Panel	Identifying whether or not systematic patterns of change exist in the use of various modes of transport given a nationwide increase in public transport fares.	The sample is of those 1031 respondents who appeared in each of the first three waves of the Dutch Mobility Panel (March 1984, September 1984, and March 1985).	Longitudinal data is required when looking at gross turnovers in mode use. The main aim of the study could probably have been achieved through a one-off retrospective data collection as changes in mode use are important enough to be remembered by individuals. However, since the study attempted to gain a better understanding of the changes by looking at trip purposes as well, panel data was probably necessary.	Potential biases in the multi-day diary were controlled using the method outlined in Golob and Meurs (1986). Bias due to attrition was controlled by weighting the sample to be representative of the general Netherlands population (perhaps not the best method that could have been used).
Goodwin, P.B. (1986)	South Yorkshire Panel Survey	Aimed to study the effects of real public transport fare reductions over time.	A panel design was used, though there were only of two waves; the later wave was just an after-thought to what was initially a cross-sectional survey. The waves were in 1981 and 1984.	A panel design may have been appropriate if the panel had been planned. However, the wave gap length is too great to be able to establish with confidence any cause and effect relationships. The dynamics of change could not be measured, only changes in use. While a panel design offers some idea of gross changes, in this case, two cross-sections may have sufficed.	The matching of respondents from one wave to the next was not greatly controlled, and it is admitted in the paper that up to 5% of the sample may be erroneously matched. There was no control for attrition other than matching, and the one-day trip diary used seems inadequate to be representative of all trips during the week.

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Goodwin, P.B. (1989)	Dutch National Mobility Panel	Panel data is used to investigate what changes occur when people have some important transitions or changes in their lifecycle, employment status, income or car ownership.	A panel, using four waves, each a year apart (Spring, 1984,5,6, and 7)	Longitudinal data is required to investigate changes in travel behaviour resulting from personal events in peoples lives, An RCS design would not be appropriate for the simple reason that individual respondents would not be able to be followed through time. Establishing causality is still difficult though, because panel data are only a series of snap-shots, not continuous.	There is no mention made of any attempt to correct for any biases, so it must be assumed that the standard corrections were performed before the data was used.
Hensher, D.A. and Le Plastrier, V. (1985)	Sydney Automobile Panel	Reports on progress towards a dynamic discrete-choice model of household automobile fleet size and composition.	A dynamic model system is used based on a retrospective survey of 354 households interviewed in 1980 as a pre-cursor to the Sydney Automobile Panel	A variable such as car ownership is one of the important lifecycle variables people find easy to recall, so for the simple purpose of modelling the dynamics of car ownership, a retrospective SCS can provide richer data than even a panel as the data can be in the form of a time series. The restriction with this approach is that explanatory variables are also limited to variables which can be accurately recalled or that are recorded somewhere.	An SCS is not subject to all the forms of error of most of the other longitudinal techniques. The only major problem is relying on the recall of respondents - wherever possible cross-checks with other data sources should be made, though this is not mentioned in the paper.
Hensher, D.A. *et al* (1991b)	Dimensions of Automobile Demand Project	1. The development of policy sensitive economic models of the household sector's demand for automobiles (emphasis on vehicle types). 2. Development of a panel data set to use in the econometric estimation of static and dynamic vehicle choice and use models for the period 1981-1985. 3. Application of these models to predict future energy use given a variety of future scenarios of cost, technology etc.	A panel survey from August 1981 to June 1985 of 1172 household in Sydney (those who participated in all waves). Personal interviews conducted at 12 month intervals obtained data on the composition and use of the household's vehicle fleet during the previous 12 months.	A panel design provided the quality data necessary for the best possible modelling. However, since car ownership decisions are important and infrequent decisions, an SCS using recall or an RCS for a larger sample size could probably have been used to collect the same quality of data at a much lower cost to satisfy the main aims. If it was felt that choice mechanisms may be confounded by 'snap-shots' of cross-sectional data, a panel survey with less frequent waves (eg every three years) would have proven just as effective.	The study controls for attrition biases in a very complete way. Firstly, survey administration and tracing techniques ensured a fairly low rate of attrition. The non-response bias that did occur was dealt with in a very comprehensive pre-analysis stage. However, the panel did not control for sample stagnation as it used no refreshing techniques to maintain the representativeness of the sample.

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Hensher, D.A.. *et al* (1991a)	The Role of Stated Preference and Discrete Choice Models in Identifying Community Preferences for Traffic Management Devices	The paper aims to demonstrate how discrete choice models combined with stated preference data can be used to identify community choices amongst alternative traffic management devices.	A two wave, before and after, panel survey was conducted of a stratified random sample of 201 Willoughby residents.	The use of a panel survey rather than a repeated cross-section seems justified for such a small study because it minimises the sampling error. Thus, the actual change in preferences is not confounded by the fact that the before and after respondents are different.	Little mention is made of controlling for attrition, and stagnation is not really a problem over 2 waves. Panel conditioning may have been a factor though, as the before survey made respondents more aware of the traffic management devices. The study notes that a major source of bias was that some respondents had overtly experienced the traffic management devices in question, while others hadn't. Those who hadn't were more likely to change their opinion of the devices. This could have been controlled by only using respondents who had previously experienced the device.
Iida, Y. et al (1992)	Panel Survey on the Effects of Travel Time Information System in Osaka	Aims to examine driver response to a travel time information system actually in operation.	Longitudinal surveys are conducted immediately after installation of the IVHS in what is a 5 wave rotating panel between April 1991 and September, 1992. Analysis is only for waves 1 to 3. A questionnaire and traffic count were the survey instruments.	Longitudinal data is necessary to study the dynamics of change and adaptation to new circumstances. Behavioural and strategic driving decisions on a particular day could not be remembered, so a panel seems essential for such a study.	Many deficiencies in the data collection process were noted, but no attempts were made to statistically correct for them.

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Jarvik, L.F. and Bank, L. (1983)	New York State Psychiatric Institute Study of Aging Twins	Study of the aging process of identical and fraternal twins in old age. The influences of life history on life expectancy are investigated.	268 subjects who entered the study prior to 1950, who still lived in New York state (or close by), were over 60 (at the time of recruitment), white, English speaking and were still alive (half were identical, half were fraternal twins) were used in the study. They underwent an initial evaluation in 1946, then were re-tested in 1947, 1955 and 1967.	Longitudinal data is required to be able to track the lives of twins and understand their aging process. It might have been interesting to have control group however. In addition, the sample became too small in the final wave to hold any statistical power.	Panel conditioning was perhaps the most significant problem in the study, but it was tested for. Panel attrition was mainly due to death, and this was of interest to the study so could not be considered a problem. There are stagnation and conditioning problems in this study which are unavoidable given such a rare population.
Kitamura, R. (1989)	Dutch National Mobility Panel	An examination of the causal structure underlying household mobility.	The first three waves of the Dutch Mobility Panel (March 1984, September, 1984, and March 1985) were used, with the household as the unit of analysis.	Longitudinal data is required for a study of causal analysis of changes in car ownership, number of drivers, number of car trips and number of transit trips. Considering the nature of these variables (ie the frequency with which people make trips by particular modes), a panel approach to data collection, with travel diaries used, seems the only appropriate design. Such information would be extremely difficult to recall if it were not collected on a daily basis over a time period. Other criticisms of the Dutch Mobility Panel such as the possibility of using a split panel design hold for this study.	Sample bias (attrition etc) was accounted for using the procedure outlined in Kitamura and Bovy (1987).
Kitamura, R. and Bunch, D. (1990)	Dutch National Mobility Panel	To address the issue of heterogeneity versus true state dependence in dynamic disaggregate choice models for household car ownership.	Four waves, each conducted twelve months apart (1984-7), of the Dutch Mobility Panel were used. 605 households formed the subsample, and ordered-response probit models with error components were used.	Longitudinal data is best for a dynamic model such as this, but a well designed SCS survey could easily have elicited the same quality of responses for car ownership and demographic variables. A problem with relying on recall for such important decisions, however, is that the reasons may have been 'post-rationalised' by the respondent.	As per Dutch Mobility Panel, but spent a lot of effort accounting for heterogeneity problem not dealt with in other studies. While admitting that the coefficient estimates are generally robust enough not to worry, they believe that using lagged dummies is not an adequate solution to the dynamic modelling problem.

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Kitamura, R. and Bunch, D.S. (1989)	Dutch National Mobility Panel	Alternative specifications of error-component ordered-response probit models are estimated and used to estimate models of car ownership, and perform tests of heterogeneity versus true state dependence.	605 households that participated in the four survey waves in spring 1984 to 1987 are used in a panel design.	A panel design was essential given the purpose of the paper to explore and solve some of the problems of model estimation unique to panel data.	This paper is an extension of Kitamura (1987, 1988) and as such relies on the work Kitamura did controlling for bias.
Kolvin, I., Miller, F.J.W., Fleeting, M. and Kolvin, P.A. (1988)	The Newcastle Thousand Family Study	The aim is to describe the use of longitudinal data to explore early risk and protective factors for later offending.	A sample of 847 families from the panel study which ran from 1947 to 1962 (when children reached 15) is used. A rating of deprivation is given to each family based on their responses, and this is compared with the later criminal record of the child brought up by each family.	A longitudinal study is necessary to obtain information on the family and its attitudes. Panel stagnation, leading to possible problems with study relevance to the present, is a problem in this type of study.	The study relied upon concepts and measures adopted by research workers thirty years ago and, as such, the data cannot be considered as reliable as data that would be collected today, simply because a lot of techniques to do with correcting the sample for biases were not understood till much later. Perhaps the authors could have made some effort to correct some of the more obvious data problems themselves.
Loos, A. et al (1992)	The Household Panel Survey in the M10 Amsterdam Beltway Study	To study the effects of a major infrastructure project on travel behaviour and travel patterns.	A before and after panel study (1988 and 1991) of 12,000 households in the affected region was made - they were randomly telephone surveyed.	A panel is preferred over a RCS because there is less chance of sampling error. It is also useful to look at gross rather than net travel shifts. It was considered the most "precise" method available to the authors.	The sample was random. Sampling method bias was recognised, but attrition and other problems were not mentioned.
Meyer, J.P., Bobocel, D.R. and Allen, N.J. (1991)	A Longitudinal Study of Pre- and Post-Entry Influences on the Development of Organisational Commitment	The aim was to quantify changes in organisational commitment of new employees who have just graduated from university.	A panel of university students about to graduate were recruited, and given that they found full-time employment, were mailed four questionnaires. One prior to job entry, then one after 1 month, 6 months and 11 months after they started their jobs.	Longitudinal data is necessary for obtaining information on attitudinal changes over time. The panel wave gap lengths seemed particularly appropriate given that it is realistic to expect changes to have occurred in attitudes over the periods chosen. This type of subjective approach to wave gap length is not often used, but intuitively it seems more appropriate than some standard, yet arbitrary length such as a year. Panel recruitment was probably necessary, but it limited the scope of the study to a very specific group.	There was some mention of attrition and non-response bias existing, but no mention of any efforts to control them.

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Mizruchi, M.S. and Stearns, L.B. (1988)	Longitudinal Study of the Formation of Interlocking Directorates	Aimed to determine the factors affecting the appointment of representatives of financial institutions to industrial boards.	Event history analysis of 22 major US industrial corporations from 1955 to 1983. Data for this period was gained from a number of private and public agencies and included information on corporation directors and financial data, information on principal affiliations and outside directors, and data on economic conditions over the period. All is aggregated to an annual level (a company year).	Event history analysis is an ideal way of observing causal factors. However, the degree of aggregation of the data influences the ability to establish causal inference (event histories have the capacity to provide almost a continuous form of longitudinal data). The technique does appear to be appropriate in this case however, though the level of aggregation might be questionable. The restrictive factor in this type of design is that it is usually necessary to rely on other people's data. This means, the data must exist, and it must be able to be trusted before event history analysis can be used.	There is no mention of any corrections for possible biases. It is only mentioned that the sample of corporations is not large enough to be able to draw any strong conclusions. Other than this, it is hoped that the original data sources are free of any systematic errors.
Morgan, J.N., Dickinson, K., Dickinson, J., Benus, J. and Duncan, G (1974)	Panel Study of Income Dynamics	The aim was to interpret trends in family well-being and establish the relationship of well-being to certain hypothesised causal factors.	A panel of five thousand American families was followed from 1968 (all family members were traced). This is a report of the first five years (the heads of original or newly formed derivative households were contacted annually and interviewed). Most families were deliberately drawn from lower income groups, so the sample was not random.	There is much value in attempting a longitudinal study of such magnitude. The design is ideal for studying the question of family well-being dynamics over time and establishing causal relationships. However, as these relationships may change over time, perhaps some form of panel updating would have been appropriate to keep the panel representative. It may have been more useful to take a random sample of the entire population rather than just a sample of low income families, as the interplay between causative factors on different groups could have been useful from a policy perspective.	There is little discussion of statistical correction for any forms of bias, though it was mentioned that after an initially large rate of attrition, attrition rates fell appreciably.
Moschis, G.P. and Moore, R.L. (1982)	Television Advertising Effects Longitudinal Study	Aims to answer questions regarding the short and long run effects of television advertising on adolescents using a panel design (most studies in this area are cross-sectional or experimental).	A two wave panel of adolescents with a 14 month wave period, with 211 useable respondents.	A two wave panel is not really appropriate for determining effects of advertising. More sampling points spaced more frequently may have been of greater value.	There was considerable attrition between the waves which was not corrected for. Panel stagnation and related problems would not have occurred because of the brief nature of the panel, however, conditioning may be a problem in a study about advertising.

Author	Study	Purpose	Design	Comments on Design	Control of Bias
Murakami, E. and Ulberg, C. (1992)	Puget Sound Transportation Panel	A general purpose longitudinal study on travel behaviour, with the ultimate goal to use the data to improve travel demand forecasts.	A ongoing panel begun in 1989 with yearly waves. The sample is stratified by residential location and mode choice. Each year there is a phone survey and a mail out/mail back component - either a travel diary or an attitudinal questionnaire.	There is much debate as to the usefulness of general purpose panels. If properly run, they do appear to provide higher quality data for modelling purposes. The paper lists four studies which have already been carried out using the data, so in this case a general purpose panel does seem to be useful.	Panel updating with in-migrants has taken place, helping to overcome panel stagnation and attrition problems. Several "care and feeding" methods were used to reduce attrition by maintaining contact with the sample. Travel diaries have been kept to two days to limit the effects of fatigue. There is no mention of panel conditioning.
Pendyala, R.M, Kostyniuk, L.P. and Goulias, K.G. (1992)	Dutch National Mobility Panel	An examination of the stability of the relationship between car ownership and income over time at a number of neighbouring cross-sections.	Panel data from waves 1, 3, 5, 7, 9 and 10 (1984 to 1987) was used, but only in cross-sectional sense. The model used and tables produced were for cross-sectional data, so the full panel data was not utilised. 485 individuals who completed all waves were used.	Using panel data to estimate cross-sectional models seems to be somewhat of a waste of the richness inherent in panel data, particularly when examining change over time. A RCS could have provided the same data, and an SCS may even have been sufficient to collect some time series data given the importance of the variables - income and car ownership.	Using panel data to estimate cross-sectional models does reduce intra-category variation, but it also introduces all the biases inherent in panel data such as attrition, aging, and conditioning that are not usually present in a cross-sectional analysis. Corrections mentioned in Wissen and Meurs (1989) were used.
Pendyala, R.M., Goulias, K.G. and Kitamura, R. (1991)	State of California Telecommuting Pilot Project	Determination of the impacts of telecommuting on household travel behaviour.	A panel travel diary survey was conducted at two points in time, one in 1988 and one in 1989. Respondents were asked to fill out the diary for three consecutive days of the working week.	Travel behaviour is a dynamic process, with behaviour changes often lagged because of habit or household constraints etc. For this reason, longitudinal data must be used to observe changes in travel behaviour, and panel data is an appropriate source. More waves at a greater frequency may have elicited a better causal picture of change however.	A control group was used for purposes of comparison, but there was attrition from both groups which was not addressed.

Author	Study	Purpose	Design	Comments on Design	Control of Bias
Peters, H.E. (1988)	National Longitudinal Survey of Labour Market Experience (NLS)	A comparison of lifecycle data from a retrospective marital history with those derived from the same individuals from panel information	Data is from the young women's cohort of the NLS for years 1978 and 1983, when questions were asked regarding marital history. This data is compared with a one-off retrospective survey of marital history firstly for consistency, and secondly for hazard model estimation.	The design is entirely appropriate for checking the worth of the vast sums spent on longitudinal studies such as NLS. The findings that a retrospective survey estimated the models as well as panel data, while both forms of data collection had small systematic errors (some to do with recall for the retrospective survey, and some to do with the panel only checking current marital status, not all the changes that may have occurred between waves), it indicates that there should be an expanded role for retrospective data collection of reliably recalled lifecycle events. [Perhaps less frequent panel waves but with each wave being retrospective is a better answer to longitudinal data collection than either of these methods alone]	There was no mention of any correction for bias, though it is assumed that the NLS has already had many studies which have shown the way in bias correction for this author.
Powers, E.A., Goudy, W.J. and Kieth, P.M. (eds) (1985)	The Iowa Study of Older Workers in Small Towns	A series of different aspects of this data set were examined by different authors in the same book. Aspects included employment behaviour after age 50, job attitudes and work values, retirement attitudes and adjustment, work/non-work orientations, changes in preferred age of retirement, health patterns, family networks and helping patterns, importance of life areas, attitudes and perceptions, and changing patterns and life satisfaction.	A panel study of later life patterns among employed men 50 years of age and older in non-metropolitan Iowa. The first wave was conducted in 1964, and the second ten years later in 1974.	This panel initially planned more frequent investigation of respondents, but for some reason was restricted to two waves ten years apart. As such, its value, considering the number of deaths and the other problems with panel data, must be questioned. Most of the topics investigated in the book do require the type of longitudinal record a panel data set can obtain, but more waves at a greater frequency may have been appropriate.	Respondents chosen for the initial wave had to be employed possibly leading to a bias against those who retire early. Biases also exist because a large proportion of respondents died between the two waves. While no mention was made of it, there was also bound to be some attrition because of those respondents who could not be traced.

Author	Study	Purpose	Design	Comments on Design	Control of Bias
Pulkinen, L. (1988)	Cambridge Study in Delinquent Development and Jyväskylä Study in Social Development	A comparison of studies of delinquent development from two different cultures in order to examine regularities in delinquent behaviour and development.	Both were panel studies conducted in the 1960's beginning at age 8-9 with several waves until the respondents were aged in their mid-twenties. Teacher and peer ratings, as well as personal interviews and criminal records were used in both cases. The English study was all male.	Longitudinal data is appropriate for studying these characteristics, and the method of comparing similar studies from different societies appears to be a very sound way of determining societal effect on behaviour and development.	There are some problems with both data sets as well as problems with comparison because one was an all male sample while the other contained both males and females. This is not to mention all the other problems associated with panels that have not been controlled for.
Quinton, D. and Rutter, M. (1985)	Parenting behaviour of mothers raised 'in care'	Studies the connections between childhood experiences and adult psychosocial functioning.	Method used was retrospective data collection during a single interview. Respondents were asked to recall their childhood, their later family, peer and work experience, their current circumstance, functioning and adjustment.	While lifecycle events appear to be able to be recalled with some reliability, it is doubtful whether emotional experiences through childhood can be accurately recalled. Thus the recall method of longitudinal data collection in this case may be a little suspect.	Methods were developed from earlier studies by Brown and Rutter (1966), Graham and Rutter (1968), Quinton et al. (1976), and Rutter and Brown (1966), though from a non-psychologist's viewpoint, these methods do not seem terribly reliable.
Reddy, S.K. and Holak, S.L. (1991)	A longitudinal analysis of the effect of market structure characteristics on competitive reaction intensity in the US Cigarette Industry.	The study explores the effects of market structure characteristics and exogenous market interventions on competitive reaction intensity over time.	Annual sales data, prices and advertising were used in a time series analysis.	The longitudinal data was collected from historical records rather than a panel. This was eminently sensible since the data is recorded and easy to obtain.	There is little bias evident in such data. The few possible biases could occur because of measurement error, or different methods of accounting among firms. It was not stated whether there were any problems in this area.

Author	Study	Purpose	Design	Comments on Design	Control of Bias
Schaie, K.W. (1983; 1990)	The Seattle Longitudinal Study	An exploration of psychometric intelligence in adulthood. The study explores changes and its differences in intelligence between and within people.	The same subjects (approximately 3000) were followed through waves in 1956, 1963 and 1970. At the 1963 and 1970 waves (later, waves in 1977 and 84 covered in 1990 paper), a random sample was also tested from the base population as a control group. Thus, the design could be classified as a split panel.	The use of a split panel seems ideal as all bias could be measured and controlled for in the longitudinal sample.	The use of a control group meant that any panel conditioning, stagnation, or biases due to attrition, could be measured and thus controlled effectively. It is hoped that this opportunity was taken.
Schmitz-Scherzer, R. and Thomae, H. (1983)	The Bonn Longitudinal Study of Aging (first 7 waves)	Did not test specific hypotheses. Instead tried to assess the psychological, social and physical situation of respondents as extensively as possible.	Sample of 222 men and women born around the turn of the century were followed from 1965 to 1984 over eight panel waves. Each wave consisted of five days of interviews and psychological/medical testing.	An in depth panel study appears to be appropriate for collecting a wide range of information on the personal dynamics associated with aging. However, it is not advisable to conduct such a study without some clear aims in mind. This study appears to have collected a lot of information, but at what cost, and to what end? Given that there was no control for panel conditioning or stagnation, the data would be very unreliable— a split panel design would be more appropriate for the type of psychological testing carried out.	There was considerable attrition, but this was mainly due to death or ill health. Given the nature of the study, this attrition could not be regarded as a problem. Panel conditioning is a problem which was in no way controlled for, and with a psychological study, one would assume this would by a major biasing factor.
Siegler, I.C. (1983)	The Duke Longitudinal Studies	These are two multi disciplinary studies focusing on providing information that describes normal aging during the later half of the life span.	One study consisted of volunteers (60-94yrs), while the other was a stratified random sample of volunteers (46-70yrs). They began in 1955 and 1968 respectively. The former had 11 waves varying from 1 to 4 year periods between. The later had four waves, one every 2 years.	Longitudinal data seems appropriate for the type of psychological data being collected, but a split panel design, or a least a random sample, would perhaps have been more appropriate and more valid.	Both samples were selected to be representative of the actual population in terms of age, sex, race and socio-economics. Because the samples consist of volunteers, bias is minimised. Using volunteers also minimises attrition, though there was no mention of control for conditioning or stagnation.
Stokes, G. (1988)	Littlemore Bus Service Change Longitudinal Study	Looks at effects of bus service levels on people's travel behaviour.	Questionnaires and travel diaries were used on the same people just prior to bus service changes (1984), then shortly after, and again about a year later.(1985). Respondents were recruited from on-bus surveys.	Panel data allows a more realistic measure of elasticities than cross-sectional data allows.	The sample was not random, which may introduce some bias, and does not address the possibility of service changes encouraging more people to use the bus.

Author	Study	Purpose	Design	Comments on Design	Control of Bias
Stokes, G. and Goodwin, P.B. (1988)	The London Regional Transport Panel	Examines year to year variation in intensity of public transport use in London.	A panel survey from 1982 to 1985 of 1500 Londoners with annual autumn waves of one week travel diaries.	The design would have been appropriate had it been carried out with zeal. Unfortunately, attempts to minimise attrition were either very unsuccessful or non-existent. As such, the dynamics which are reported are at best only a possible trend.	Major attrition biases in the data set (over 60% attrition between each wave) virtually renders the data cross-sectional rather than longitudinal.
Supernak, J. (1992)	San Diego I-15 Carpool Lanes Panel	Evaluation of the effectiveness of a reversible roadway for high occupancy vehicles.	Panel survey of three waves, 1988, 89 and 90, though it was not originally intended to be a panel. Interviews were by telephone of potential users of the facility (481 participated in all three surveys).	Longitudinal data is necessary to look at the dynamics of travel behaviour changes. If the panel was originally intended, some retrospective component could have been used in each questionnaire to provide some valuable time series data which gives a more accurate picture of the timing of change.	There was 28% attrition between first two waves, with no refreshment.. In 1990, three fresh groups of respondents were added, each found by a different sampling method to evaluate potential biases in the sampling methods and panel conditioning. Conditioning, stagnation and attrition were corrected at the pre-analysis stage.
van Wissen, L. and Meurs, H. (1989)	The Dutch Mobility Panel	An overview of the history and research experiences, looking especially at the sampling strategy, controls for bias, and the policy goals. After years of cross-sectional data, policy makers realised that causal relationships between exogenous factors and mobility responses often involved temporal lags and other dynamic features that could not be analysed using the current data, so they suggested a panel.	10 panel waves at 6 month intervals from March 1984 till March 1988, with the waves then becoming yearly till 1989 (and beyond). Refreshment samples were taken each March.	A panel design is ideal for capturing data on the dynamic of behaviour change, as was the aim of the project. The only questions are regarding the sources of bias in the panel, which a split panel may have helped to overcome. The design, not quite a rotating panel, but a refreshed panel, should help control for a lot of conditioning and stagnation bias. In this paper, many of the rarely mentioned problems with panel data were acknowledged, thus indicating that the attempt to control for bias was very thorough.	Attrition bias was large, and was overcome using reweighting procedures. Because of week long travel diary, there was a lot of within wave bias as there were higher nonresponse rates towards the end of the week. These were also partially corrected at the pre-analysis stage.

Author	Study	Purpose	Design	Comments on Design	Control of Bias
Winner, I.S. and Moore, W.L. (1989)	Coffee Brand Purchases from Scanner Data	Evaluating the effects of marketing-mix variables on brand positioning.	Shopping centre scanner data representing 16 months of purchases for 597 households were used.	Scanner panel data is about the highest quality data possible as it allows a perfect time series analysis approach, with no data problems. Unfortunately, it does not reveal the behavioural processes behind the decisions to buy a particular brand or grind type of coffee. Thus, while being able to evaluate the effects of marketing mix variables on sales in a quantitative sense, it is impossible to have any qualitative indication as to the behavioural process leading to the change.	Aside from computer or operator error, the data is without most of the normal biases of panel data (such as conditioning and attrition) but stagnation is still a problem over 16 months as the same group is followed without refreshment.
Wrigley, N. *et al* (1984) Wrigley, N. and Dunn, R. (1984a,b,c and 1985)	The Cardiff Consumer Panel	A general purpose panel looking at the broad spectrum of urban shopping behaviour in Cardiff. NDB (negative binomial distribution) and other stochastic panel data models are used in analysis.	The panel obtained continuous records on all aspects of daily food and grocery shopping for 454 households over a 24 week period in 1982, including the name and location of each store and the mode of transport to the store. Recruitment was a random stratified sample.	Panel data is essential for such models, as is illustrated in the paper. Much better estimates are made at the individual store level than at the aggregate levels previously used. This type of information cannot be collected retrospectively because recall is not very reliable for obtaining purchasing and detailed travel behaviour. A repeated cross-section would also have been pointless for the purposes of the modelling, and it would have been much more cumbersome than a panel anyway.	Considerable care was devoted to panel recruitment, panel control, panel remuneration and fieldworker control in order to minimise attrition. Sub-contracted the transfer of the coded diary onto computer tapes to a specialised computing firm who conducted more than 30 tests for consistency, range and logic. There were no statistical corrections for lack of representativeness of the sample because of non-response bias, but the panel is short enough to avoid stagnation problems.
Wunnava, P.V.(1988)	Panel Study of Income Dynamics	Focus on the shape and relative age-earnings of union and non-union members.	Data from 1968 to 1981 is used, of 946 white male household heads (the only ones who could be followed throughout the whole period). The focus is on one time switchers so as to circumvent modelling problems, heterogeneity bias, selectivity bias and bias due to measurement errors. (Weighted non linear least square probit technique used for analysis)	A panel technique seems appropriate for this type of study, though the information could possibly have been collected from other sources more easily and accurately than using a panel and relying on true reporting of income. If access was agreed to by the employee, employers should have records of changes in income and union membership that would be far more accurate and maybe cheaper to obtain.	Stagnation is one of the major problems over the 13 year time period, as the sample is not updated.

Author	Study	Purpose	Design	Comments on Design	Control of Bias
Wurzel, E. (1990)	The German Socio-Economic Panel	Examines the impact of individual economic and demographic characteristics on the distribution of single spell unemployment durations.	Data is from the first two waves (1984 and 85) of the panel comprising 6000 households and more than 12000 people over 16. (See Hanefeld, 1987 for details)	The panel approach, with retrospective data captured at each wave, is very useful as it provides a time series of data, allowing the use of continuous time models. It is unknown as to the reliability of the sample as many details are unknown.	Unknown

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