The Dutch Mobility Panel: Experiences and Evaluation

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ABSTRACT

The aim of this paper is to give an overview of the history and research experiences of the Dutch National Mobility Panel. Attention is given to the sampling strategy, the policy goals, and the representativity of the panel. It also tries to evaluate the research outcomes in terms of the original objectives and in view of more general research and policy goals. In sections one and two, a historic overview is given, starting from the first ideas to implement a longitudinal research instrument, to transportation planning. In section three, some attention is devoted to longitudinal versus cross-sectional analyses. In section four, the sample design is treated in some detail. Next, various forms of bias are discussed that affect the representativity of the panel. In the sixth section, an overview is given of the research conducted with the data. Some conclusions are given in the final section.

THE DUTCH MOBILITY PANEL: EXPERIENCES AND EVALUATION

1. INTRODUCTION

In recent years, the collection and analysis of longitudinal survey data has been incorporated into transportation science. Early examples of the application of longitudinal surveys have been reported by Jones, et al. (1983), Goodwin (1986), and Smart (1984). More recently, three major longitudinal projects have become well known in the transportation field: the Sydney automobile panel (Hensher, 1984a, 1984b, 1986), the Cardiff Consumer Panel (Wrigley, et al., 1985; Wrigley and Dunn, 1984a, 1984b, 1984c, 1985), and the Dutch Mobility Panel (Golob, Schreurs, & Smit, 1985).

The Sydney and Cardiff panels were designed for specific purposes and were privately funded. The Sydney automobile panel is a four-wave survey of 1,436 Sydney households covering the period 1981-1985. It focuses on automobile ownership (holdings and transactions), fuel consumption, and usage. The Cardiff data cover a continuous 24-week consumer panel of the shopping behavior of 454 Cardiff residents. Its main aim is to describe and analyze the major changes in grocery shopping behavior in the eighties. The Dutch Mobility Panel, on the other hand, is designed as a general purpose longitudinal travel survey (Golob, Schreurs, & Smit, 1985; Baanders and Slootman, 1983) and is financed exclusively by public funding. [1] Although, to date, the data have been used primarily for

[1] The survey is sponsored by the Projectbureau for Integrated Traffic and Transportation Studies and the Directorate General of Transportation of the Ministry of Transport and Public Works.

evaluation of public transport policies, the range of possible applications is broad. The panel began in 1984; in 1988, the ninth wave was collected. A tenth wave is planned for March 1989. Of these nine waves, seven contain complete seven-day travel diaries for the respondents. The sample size is approximately 1,800 households per wave, making it the largest longitudinal travel survey ever conducted. The panel is one of the major resources for describing and understanding changes in mobility behavior in the Netherlands in the eighties.

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2. A BRIEF HISTORY

In Dutch policy making, the need for empirically-based, policy-oriented research has been recognized for a long time. In the seventies, a large annual repeated cross-sectional survey was designed and implemented for general use in policy planning and research (Moning, 1983). This sample is used mainly to describe aggregate mobility trends and to calibrate transportation models. While this sample is, in general, very useful for policy applications, it was soon recognized that causal relationships between exogenous factors and mobility responses often involve temporal lags and other dynamic features that cannot be analyzed using cross-sectional data. Therefore, the idea of a longitudinal travel survey instrument was developed within the Dutch Ministry of Transport (Baanders and Slootman, 1983). Longitudinal analysis and panels were already introduced in sociology and marketing

research in the seventies and it appeared that the basic motivations for using these types of data were equally applicable in transportation planning and research. The initial concept, expressed in the Baanders and Slootman paper, was to create a "general purpose" longitudinal data source that allowed in-depth analyses of the determinants of changes in mobility and rapid access to respondents for current policy issues.

The "start-up" phase of the panel is described in more detail in Golob, Schreurs, & Smit (1985). Preliminary research was undertaken to design a general purpose longitudinal survey. In the course of the preparatory stages, a second research goal was identified: the evaluation of a new public transport fare policy for the period 1984-1987. This is characteristic of the history of this long term research project: It has constantly adjusted to changes in the current policy conditions and research objectives. The sampling frame was adjusted to fit into this second policy goal.

The first wave of the panel took place in March 1984, just before the first fare increases. Initially, two waves per year were planned, so the second wave took place in September 1984, and the third in March 1985 (see Table 1). This was to allow the identification and estimation of both a yearly trend (March-March comparisons) and a seasonal trend (March-September). The first analyses aimed at detecting and quantifying the implications of the fare policies (BGC, 1985a, 1985b). However, it was immediately clear from these analyses that panel attrition and measurement problems hindered a simple "naive" descriptive approach to the data. The estimated overall downward trend of total mobility was not observed in other sources and traffic counts. Although the analyses clearly showed the differential impacts of the fare policies among population segments, the overall performance of the panel for evaluation of the public transport policy was unsatisfactory.

Table 1: An overview of the panel waves

WAVE	DATE	RESPONDENTS House-holds	RESPONDENTS Persons	QUESTIONNAIRE	OTHER
1	March 1984	1,764	3,863	Full + Personal restrospective 7-day train diary	interviews
2	Sept. 1984	1,673	3,802	Full + retrospective 7-day train diary	Mail interviews + personal for starters
3	March 1985	1,687	3,814	Full + retrospective 7-day train diary	Personal interviews
4	Sept. 1985	1,427	3,316	Household questionnaire + interview retrospective train usage questions	Mail
5	March 1986	1,849	4,133	Full	Personal
6	Sept. 1986	1,754	3,997	Full	Personal
7	March 1987	1,926	4,329	Full	Personal
8	Sept. 1987	*	*	Maintenance contact + attitudinal questionnaire	
9	March 1988	1,759	3,916	Full + retrospective residential/ workplace mobility	No panel refreshment
10	March 1989	*	*	Full	Planned

(* = not yet available)

In the next year attention was heavily focused on methodological aspects of panel sampling and possible methods to produce unbiased population estimates. These methodological analyses uncovered numerous methodological aspects of longitudinal analysis of multi-day travel diaries and the results indicated that adequate correction procedures for panel biases could be developed (this issue will be elaborated in more detail in section five). Consequently, budgets were allocated for three new waves in March and September 1985 and in March 1986. The analyses undertaken with these new waves used the correction procedures developed earlier. The policy focus had shifted too in this period: The fare policy was more or less abandoned in 1985 and more general aspects of public transportation and mobility became the focus of interest. Analyses focusing on these topics will be described briefly in section six. Work along these lines is still continuing.

Each year, research budgets must be allocated in the Ministries. The funding of the panel, although a long-term project by nature, is therefore the outcome of a series of yearly evaluations. The history of this project shows that the adaptability to new policies and research questions is a necessary condition for a long-term government funded research project. If the project is tied to specific policies or groups then the possibility for long-term funding is small. However, major longitudinal research projects can only be funded if they can contribute to specific policy questions. This dilemma is not easily resolved unless two conditions are met: First, the data should allow a broad range of applications; second, there should be a continuous demand for empirically based analyses of policy relevant issues.

In 1987, a round table conference of policymakers, policy analysts and researchers was organized by the Ministry of Transport and Public Works to evaluate the panel project. At the conference, a distinction was made between descriptive and causal analysis purposes

of the panel. Policy questions were mainly towards descriptive population statistics (e.g., how many users have changed to and from public transport). However, it was concluded that the chosen sampling design is not optimal for this purpose. Instead, the design favors causal longitudinal analyses (Analysis of Panel Data, 1987, p. 221). So, from a specific policy-making point of view, the panel had not lived up to its expectations. On the other hand, much research has been and is still being conducted on various aspects of the dynamic aspects of mobility. Moreover, many methodological issues have arisen and been resolved that are valuable beyond the specific policy contexts of the panel project. For the future of the project, significant new policy questions had to be addressed, such as the consequences of the dramatic increases in car-ownership and usage. This poses important questions such as:

* What causes car-ownership levels to change?
* Is the increase in car usage simply the result of increased levels of car ownership, or a more fundamental trend?
* Is the increase in car usage a substitution effect from other modes to car, or is it the generation of new demand?
* How can the modal split be affected?

Due to the general nature of the panel it can make substantial contributions to many of these types of questions. With the increase in the number of waves, more types of analysis are possible. In March 1989, the data cover a period of five years (1984-1989), including eight completed panel surveys.

3. WHY PANELS IN TRANSPORTATION?

A panel survey is one which involves repeated measurement on the same sample of units at different points in time. The timing of the measurements (waves), the sample design, and the methodologies used may differ considerably among panels (Hensher, 1987). The Cardiff panel involves daily measurements over a 24-week period, whereas the Dutch Mobility Panel is a long-term panel with six-month or yearly intervals between seven-day travel diaries. In a "pure" panel survey sample, units are sampled at the beginning of the survey period and the dropouts are not replaced by new recruitment. In rotating panels, units are dropped at fixed intervals and replaced by new ones (for an extensive overview, see van de Pol, 1987).

There are various motivations for using a panel in transportation planning and research. There were four main motivations for starting the Dutch Panel. The first reason involved the advantages of detecting changes at the personal level using repeated measurements. Repeated observations of the same individuals generally gives more precise measurements of changes in individual mobility behavior. Thus, the effects of transportation policies, which are usually in terms of changes in trends can be detected more easily using repeated (paired) observations of the same individuals. Second, the history and experience of a person can be very important in explaining current behavior. For instance, whether a person has used public transport in some prior time period or not may be very important in explaining how he or she responds to specific policies aiming at increasing the share of public transport. Moreover, changes in individual or household circumstances may have an impact on changes in mobility characteristics. However, measurement and identification of

these effects may be obscured by time lags. Car-ownership levels are likely to change with a certain time lag to changes in transport costs. Only longitudinal data make it possible to detect these lagged individual responses. Third, in cross-sectional surveys it is often very difficult to disentangle various causes of mobility responses. Many factors may influence individual travel behavior, and it is not always clear what the true underlying causal structure is. Longitudinal surveys offer, in principle, the possibility of focusing on the variable(s) of interest and removing the possible bias of various time independent observed and unobserved factors. Thus, a longitudinal survey has a high potential for answering "why" questions. The fourth reason is a very practical one: An established panel sample provides rapid and inexpensive access for specific policy-relevant issues. The sample can provide the sampling framework for smaller subsamples directed at specific sub-populations. Since a large amount of information on each respondent is already available, the questionnaire can usually be very small and focus on the matter of interest.

Despite these definite advantages, there are a number of drawbacks to implementation of a longitudinal survey (see also Harway et al., 1984). First, there are financial and organizational difficulties: The total costs of the project are usually considerably higher than a one-time cross-sectional sample. It also necessitates a longer-term research planning horizon. In the previous section it was pointed out that this can be potentially dangerous for the completion of a long term project. Moreover, continuity in the key positions in the staffing of the project (both in planning and research) is important. The second problem involves the quality of the sample. The sampling strategy of longitudinal surveys is more demanding then cross-sectional sampling. The question of representativity must be addressed. Is there a need to be representative and, if so, what is

the theoretical population? For example, a distinction can be made between representativity of the total population at each point in time, or of the initial cohort. Initial sampling probabilities and dealing with panel attrition and refreshment must also be addressed in the sampling scheme. Section four addresses the sampling strategy of the Dutch panel in more detail while section five focuses on biases that result from sampling errors.

Much more can be said about the advantages and disadvantages of longitudinal analyses from a methodological point of view. Since the seventies there is a growing volume of literature on the methodological aspects of this issue. For an extensive discussion of this topic in general, see, e.g.: Tuma and Hannan, 1984; Hsiao, 1986; Davies and Pickles, 1987 or Wrigley, 1987. More transportation oriented contributions are: Goodwin, et al., 1987; Kitamura, 1986; Hensher, 1987).

4. THE DUTCH MOBILITY PANEL SURVEY

4.1 Sampling Strategy

The theoretical population of the sample consists of all household members aged 12 years and older in the Netherlands. The sampling unit is the household, since the household is the most appropriate unit for studying the interacting mobility patterns of individuals. For transportation planning purposes, the mobility behavior of children under 12 years is not relevant, except when it involves serve-passenger trips of older household members. Between March 1984 and March 1989, nine waves were collected. A tenth wave is planned for March 1989. Table 1 gives an overview of waves one through nine. In Figure 1 the

dynamics of the panel sample is shown.[2] The total sample is divided into a number of subsamples, distinguished by time of entry. For sampling purposes the distinction between the initial sample and the refreshment samples is useful. Each has its own sampling strategy. To ensure enough households in policy-relevant subpopulations a stratified sampling scheme was chosen. Previous research, reported in van Wissen, et al. (1985) had shown that three variables were optimal for stratification: income, life cycle, and region of residence. The last variable reflects different levels of service of transportation networks. For budgetary reasons, a clustered sample was used: Within each region of residence a few carefully selected municipalities were chosen. With these three variables, a total of 40 different subcategories (strata) were defined. Sampling was performed randomly within each stratum with the sample size determined by an adequate level of public transport users (for more details, see BGC-ILBO, 1983; Golob, Schreurs & Smit, 1985). This latter requirement merely involved an extra question in the screening questionnaire. In addition, total size was estimated to be approximately 2000. This sample size allowed both general purpose use and specific public transport related analyses. After completion of the first wave, complete data were gathered for 1,764 households.

The field work for a panel survey is basically different from a cross-sectional survey in a number of respects. First, it is important to establish a long-term contact between surveyor and respondent. This proved to be crucial in maintaining a high repeated-response rate from wave three on. In contrast, the low response rate of the second wave was largely attributable to the mailing of the questionnaire. By re-surveying the household by the same interviewer, a repeated-response rate of ± 85 percent was achieved in later waves. Second,

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[2] Only the spring waves are included.

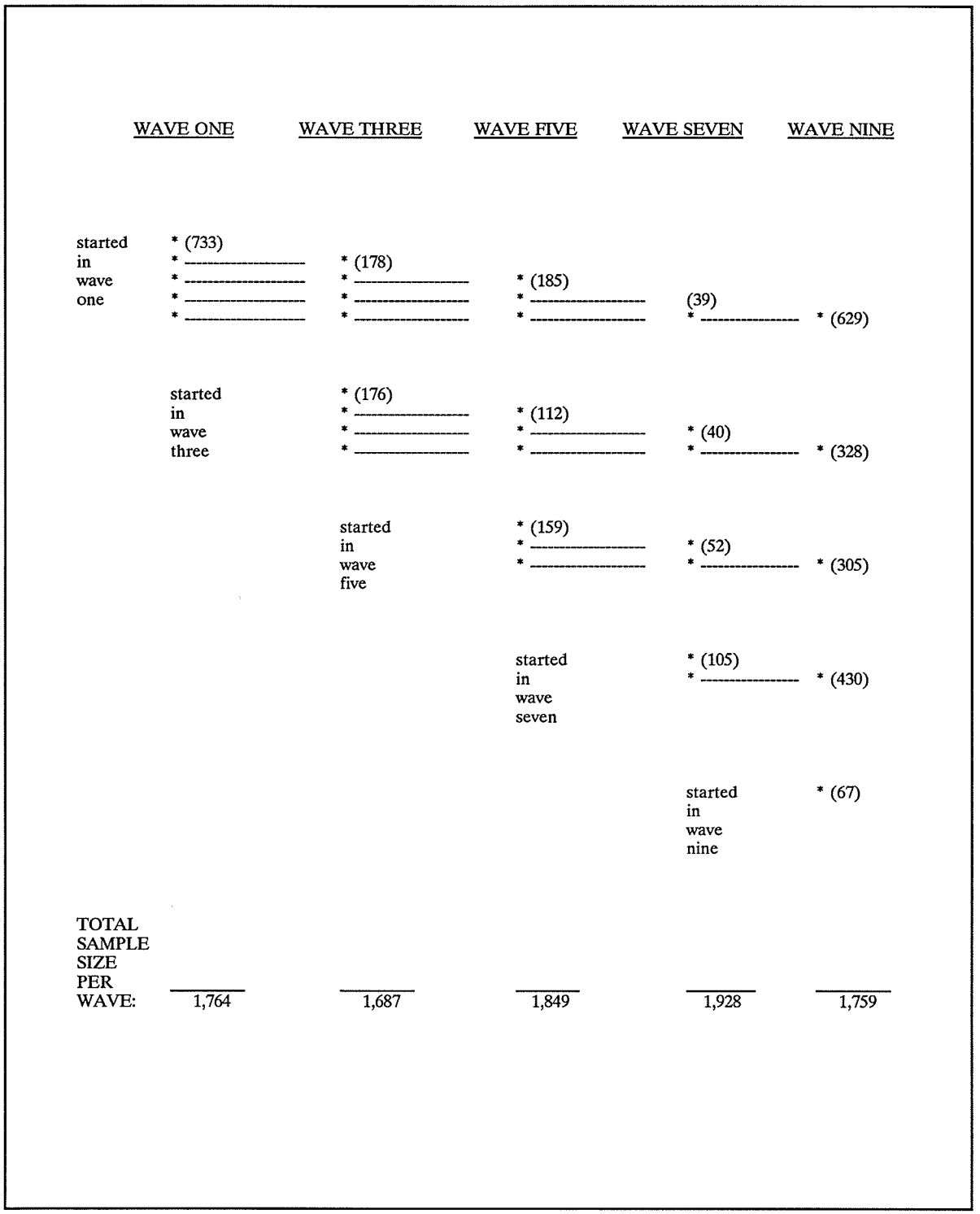

Figure 1: Panel dynamics, sample size, attrition and refreshment of households for waves one through nine

regular contacts are necessary, with a maximum interval of six months. Therefore, wave four and wave eight consisted merely of small maintenance contacts, with only a small number of questions asked in wave four. Third (and more specific for a multi-day travel survey), in order to eliminate all possible sources of measurement error in comparing individual mobility across waves, each individual travel diary has to start on the same day in each wave. If a person starts on a Monday in wave one, he should start on a Monday in all subsequent waves. This is because there is a systematic influence of starting day on reported mobility (see also Golob and Meurs, 1986).

Since the sampling probabilities of each subcategory were known, it was believed that through reweighting of the stratified sample, unbiased population estimates of mobility levels could be derived, while separate analyses could be conducted for various subpopulations (e.g., low income households, the elderly, etc.) Figure 2 depicts the results of the initial sampling. In the first stage, 6,128 randomly sampled households in the chosen communities were contacted, of which 3,242 refused to cooperate or could not be contacted. In the second phase, the remaining 2,886 households were screened and a selection of 2,185 households (the "initial panel") was made. Although this group had already agreed to participate, 421 refused to respond in the wave 1 questionnaire. This left 1,764 households which completed the first wave.

As can be seen in Figure 1, the total sample size of the panel depends on the period under study. The true longitudinal panel that survived until wave 9 is 629 households. The wave 1 - wave 7 panel comprises an additional 39 households. From wave 1 through wave 5, 853 households survived in the sample, and from wave 1 through wave 3 exactly 1,031. From this figure the decrease in dropout with increasing panel participation can be deduced.

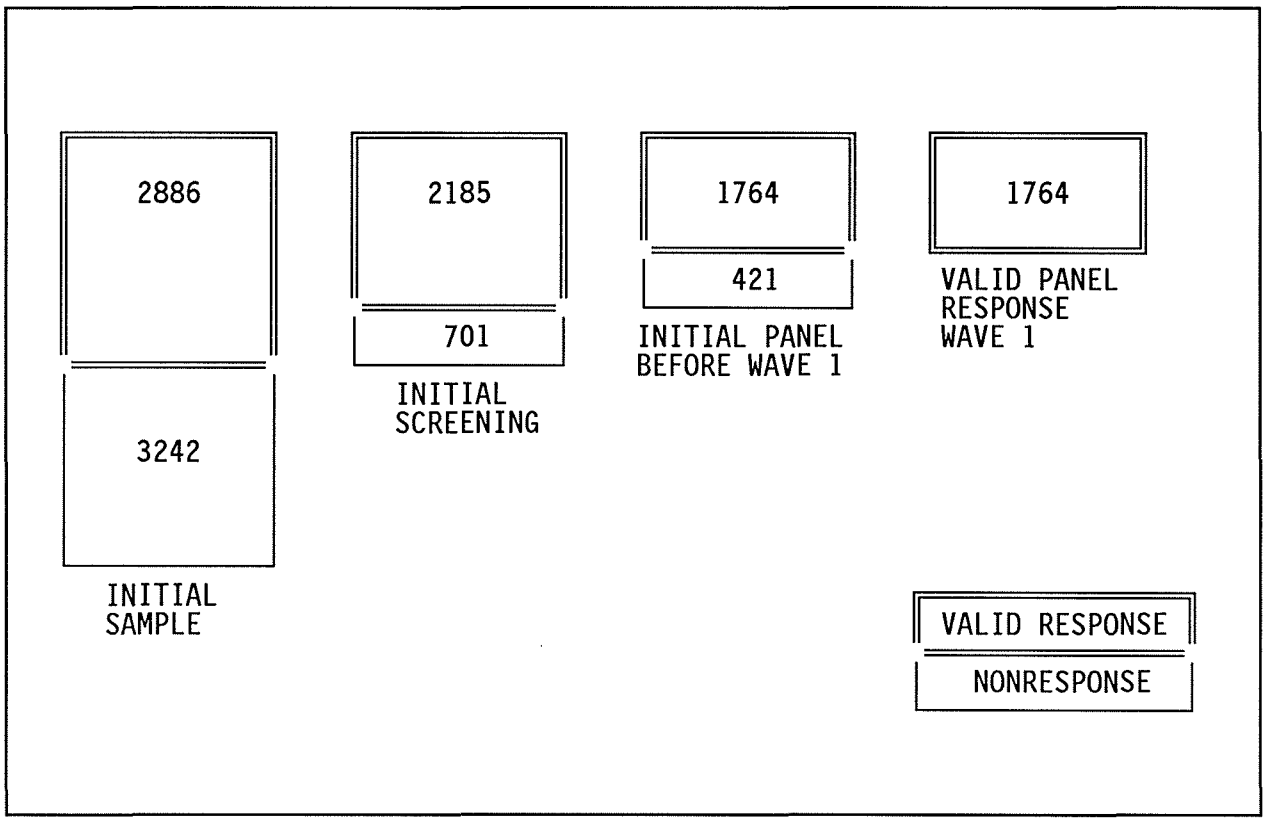

Figure 2: Results of initial sampling

Of all participating households in wave 1, 58.4 percent participated in wave 3: a dropout rate of 41.6 percent occurred during the first year. Of the remaining 1,031 households, only 178, or 17.3 percent, dropped out during the second year, and the third year showed a dropout rate of 21.7 percent. The first year dropout rate of households which started in wave 3 was 26.8 percent, while the second year rate was 23.3 percent. Note that between wave 3 and wave 5 only a small maintenance survey was conducted, while between wave 5 and wave 7 a complete travel diary was administered. Wave 8 involved only a maintenance contact without surveying. To maintain an equal total sample size in all waves the panel

dropouts are replaced by new panel recruitments. The sampling strategy used in the new recruitments is to reflect the composition of the dropouts, taking into account the gradual changes that take place in the population as a whole. Through panel refreshment the sample can be updated and reflect changes that take place in the population. Another important element of the panel design is that household formation, residential relocation, etc., are followed in the sample. This internal changes in panel household composition and residence reflects population dynamics and enables the panel to change gradually in a manner similar to the population. Moreover, it allows the analyses of important interactions among these events and various aspects of mobility. This process of new household formation within the panel accounts for the 67 starting new households in wave 9.

4.2 The Questionnaire

In each wave, all household members aged 12 years and older were asked to complete a continuous seven-day travel diary. In addition, in each wave, both household and personal questionnaires were collected containing basic demographic and economic data. Further, additional questions were sometimes asked per wave. In the first three waves, a separate retrospective seven-day train diary was included. In wave 9, additional questions concerning changes in work place and place of residence were asked. Essentially, the three-part questionnaire remained unchanged, except for some adjustments to correct for observed ambiguities in the car variables. Basic demographic and economic data on the household and household members include:

* Age, sex, position in the household
* Life cycle and household size
* Income (personal and household)

* Place of residence
* Education and profession
* Car ownership
* Fuel type, weight, and other characteristics of the car
* Travel subsidies for work trips
* Fare type(s) paid for public transport.

The travel diary involves seven days of travel recording. Respondents are asked to fill in all trips over 500 meters. For each trip, the following information is asked:

* Mode(s) used in the trip
* Purpose of the trip
* Departure and arrival times
* Total distance traveled
* Travel time per mode.

A seven-day travel diary is long, even for a cross-sectional survey. It allows analysis of weekly travel behavior, even without taking into account the longitudinal character of the data (see, e.g., Pas & Koppelman, 1987). However, it imposed several methodological difficulties in a longitudinal context, as will be elaborated in the next section.

5. BIASES AND CORRECTION PROCEDURES

In this section the issue of various forms of biases will be discussed in more detail.

Meurs, et al. (1988) developed a model that captures the most important elements of these biases.

The quality of the data hinges on three aspects. These will be discussed separately below:

1. Initial nonresponse. The level of nonresponse in the first wave was not randomly distributed among the stratification variables (BGC, 1985b, 1985c; Golob, Schreurs, & Smit, 1985). In particular, singles, one-parent households, retired households, and lower income groups showed a higher than average initial nonresponse rate. Moreover, nonresponse was much higher in the large cities.

2. Panel attrition. A significant number of households drop out after each wave. The composition of these dropouts is nonrandom (see Kitamura and Bovy, 1987; and below). Lower income households, singles, and retired households, in particular, tended to drop out, thus resembling the initial nonresponse pattern.

3. Measurement errors. This can be decomposed into two sources: within-wave bias and between-wave bias. The within-wave bias is related to fatigue effects that occur over the seven days of travel reporting. Between-wave biases refer to reporting errors that occur over the waves: panel effects, long-term fatigue effects, etc.

Both nonrandom initial nonresponse and attrition can be remedied by applying reweighting procedures based on the stratification variables. The weighting factors are a combination of initial sampling probabilities, initial nonresponse, and the dropout rates per

cell. This procedure is, in the case of the Dutch Panel, very simple, since an accurate estimate of the population distribution is available: the National Travel Survey (Moning, 1983). More details concerning this procedure can be found in BGC (1985c). Panel refreshment is used to counteract the changing composition of the panel due to nonrandom dropout.

The nonrandomness of the panel attrition is more complicated. The composition of the dropouts of the panel is different from the stayers. This is depicted in some detail in Table 2. For the subsample of the panel that started in March 1984 an analysis was conducted to relate individual panel duration to various characteristics. Table 2 is a summary of the main results of the analysis. Respondents who live in the large cities have a higher then average dropout rate. Both low and high income groups show a higher attrition rate than middle income groups. Educational level has a positive effect on the probability of participation in wave 2. Finally, there is a negative relation between the total mobility level and the probability of participating in wave 2. So, dropout between wave one and wave two is both biased in terms of background variables and mobility. These results are similar to the analysis by Kitamura and Bovy (1987). However, as respondents participate in more and more waves, the dropout tends to become more random. Dropout in wave 3 for those who stayed in the first two waves again shows a correlation with residence in large cities, lower education level and total trips, but dropout in wave 5, given that the respondent stayed in waves 1 through 4 is only related to residence in large cities and total mobility. The corresponding result for dropout in wave 7 for those who stayed in the first 6 waves shows a completely random dropout: no significant relations emerge.[3]

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[3] The lack of significance in later waves is partly due to the decreasing sample size with increasing panel duration.

Table 2: Wave one respondents:
Personal characteristics related to panel dropout per wave

VARIABLE	DROPOUT				
	Wave 2	Wave 3	Wave 5	Wave 6	Wave 7
Living in large cities	+	+	+		
Low income (Fl. 0-17 K)	+			+	
High income (Fl. 38+ K)	+				
Low education	+	+			
High education	_				
Age 12-17				+	
# licenses in household	-	+			
Total trips	-	-	-		

Even if the sample is corrected for nonrandom attrition in terms of background variables, the dropouts are less mobile than the "stayers" (continuous reporters). One explanation for this phenomenon is given by Kitamura and Bovy (1987): Respondents who are likely to drop out tend to under-report trips more than the continuing respondents. Their analysis shows some evidence in this direction. BGC (1985c) proposed a correction

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procedure for this selectivity of the attrition in terms of mobility. This procedure is based on the comparison of the mobility distribution in the base wave with the distribution of the "stayers" in the wave after the dropout has occurred. Weights are calculated that "expand" the second wave distribution to match the initial mobility distribution. The underlying premise in this approach is that the aggregate mobility distribution is stable over time. Details of this procedure can be found in BGC (1985c). The method is rather cumbersome, however. It appeared that it corrected the attrition bias in mobility but that this bias was not the only source of error. These other sources are called within-wave and between-wave measurement errors.

On average, respondents tend to show a declining trip rate in the course of seven days (Golob and Meurs, 1986). Since it is highly unlikely that there is a true decline in trip rates, this nonzero association with sequence day is attributable to reporting errors. In multi-day travel diaries, this phenomenon is well known (see, e.g., Szalai, 1972; Brög and Meyburg, 1980, 1982; Lyn and Ruchon, 1979; Clarke, et al., 1981), but imposes several additional problems in longitudinal surveys. As explained in Meurs, et al., 1988, the within-wave bias tends to be correlated with prior panel experience. The within-wave bias is largest in the first participating wave, and flattens out in later participating waves. This implies that a part of the between-wave differences is attributable to varying within-wave bias over the waves. There is also a true between-wave bias. After accounting for differential within-wave biases and other sources of variation, there is a difference in mobility between starters and stayers. If the refreshment sample (the starters) are randomly chosen from the population then this between wave bias can be corrected for.

6. RESEARCH EXPERIENCES WITH THE PANEL

In the course of the project, analyses of various types have been performed with the panel data. These topics include both substantial analyses that are relevant for transport policy and methodological oriented contributions. Here the major research areas that have been addressed using the panel data will be summarized.

6.1 Dynamic Travel Demand Analysis

The first research area can broadly be defined as dynamic travel demand analysis. This comprises (1) the individual choice of travel mode, and (2) trip generation and distance travelled by mode. Each of these will be discussed below.

The first analyses of changes in travel mode were performed using the first year data. In Golob, et al. (1985) a two period multi-mode turnover analysis is reported. A turnover table is a table resulting from the cross-classification of individuals by use of travel mode in two or more time periods. Public transport is subdivided into: (1) train, and (2) bus-tram-subway (btm) usage. In these types of analyses a person is defined to be a mode-user if he has made at least one trip in that mode. For public transport policy this was considered to be an important variable since it separates the population into users and non-users. This analysis was extended in Golob et al. (1986) where a separate users/non-users analysis was conducted for every mode with three points in time. The three-fold tables enabled the identification of a component related to the overall yearly usage trend, a seasonal component and a component related to the fare policy. By comparing various

market segments (population groups) the differential impact of these components on mode usage could be identified. However, interrelations among the modes are not included in this approach. This shortcoming is overcome in van Wissen and Golob (1988). They present a general model of turnovers in modal choice where all modes are treated simultaneously and exogenous variables are present. In their application (changes in) car ownership levels have a major impact on the dynamics of modal choice.

The analysis of dynamic aspects of trip generation has received considerable attention. In Golob and Meurs (1987, 1988) the intertemporal relations among trip rates by modes has been studied in depth. This allowed both for tests of stability in modal trip rates, and (lagged) competition and complementarity among modes. In Golob (1988a, 1988b) the analysis is extended to include car-ownership and income. Golob (1988a) investigates the issue of temporal stability of interrelations among the variables. Here, car ownership is treated as exogenous, which implies a short-term perspective on the mobility process. In Golob (1988b) and Kitamura (1987) car-ownership is treated as an endogenous variable. Both use simultaneous equation systems. Kitamura considers total trips at the household level and finds no effects of car-ownership on total trip generation. Golob considers multi-mode trips at the individual level and concludes that car-ownership has differential effects on various modes. In Golob and van Wissen (1988) the same approach is used in the analysis of the joint effects of distance generation, car-ownership and income.

In general, results of these analyses show that changes in car ownership are the lagged response to increased mobility. Many influencing factors (e.g., income, life cycle) show a contemporaneous (instantaneous), as well as lagged, effects. This implies that long-term elasticities estimated from cross-sectional data may be biased. Further, even

contemporaneous effects estimated with cross-sectional data may be seriously biased. Meurs (1988) estimates a model of trip generation where an attempt is made to improve parameter estimates of exogenous variables and the temporal trend by using so-called "fixed-effects" and "random-effects" models. These methods eliminate the bias due to unobserved individual- (household) specific effects. The results indicate that without controlling for these unobserved effects, the use of linear trip generation models with cross-sectional data should be seriously questioned.

6.2 Dynamic Activity Analysis

Several attempts have been made to study the dynamic properties of activity behavior with the panel. Kitamura and van der Hoorn (1987) use weekly patterns of the panel to study the regularity aspects of activity behavior. Their results indicate that lagged responses and habits (inertia) are important aspects of activity behavior. Kitamura (1988a) extended the concept of history dependence in daily activity behavior in assuming that daily travel patterns vary from day to day around several latent "representative" patterns. The latent patterns appeared to be strongly history dependent. Another approach is taken by Recker et al. (1987) and Golob and Recker (1987). Here, travel behavior is decomposed in three dimensions: space, time, and type of activity. Pattern recognition techniques and non-linear transformations are used to study regularity of travel patterns. The data used in this application come from a subset of the panel. For waves 1, 2, and 3, all trips of the panel-members living in the Amsterdam region were geocoded for detailed longitudinal space-time analyses.

Yet another approach is centered around so-called "activity profiles." Here, the seven-day travel diaries are converted into a continuous time-distance activity profile. In BGC (1988a), these activity profiles are used to study travel behavior in peak hours. In van Wissen, et al. (1989), a dynamic multivariate model of activity times, including travel time, is estimated. A major finding of this study is that the allocation of time to various activities is relatively stable over time. Moreover, travel time is derived from the time allocated to other activities. A related approach is taken by van Wissen (1989), who studies interactions among household members in time allocation. Finally, Golob (1989) studies travel time budgets in a longitudinal context. The ongoing work in this field indicates that dynamic activity analysis has the potential of offering deep insights into the major determinants of daily activity and travel behavior.

6.3 Methodological Research

As pointed out in the historical overview, the panel project has always had a strong methodological aspect. A number of papers have been produced on biases in and between waves. In section 5, various aspects of these biases were discussed in more detail and relevant references are given therein. Further, valuable contributions have been made in various aspects of travel demand modeling: trip generation, mode choice, and car ownership. Many technical problems exist in formulation and estimation of these models that are not resolved yet. Indeed, dynamic models are in general technically more difficult, and this is a drawback in applying them as practical planning tools. Future work using the panel should also focus on practical ways of incorporating dynamic research methods for planning and forecasting. One promising attempt in the practical application of dynamic

models is make by Kitamura & Goulias (1989). Here a dynamic life cycle and car ownership model is developed and estimated with the Dutch panel data.

6.4 Other Contributions

A large number of policy-oriented research reports have been written (BGC, 1985a, 1985b, 1986, 1987a, 1987b; 1988a, 1988b; Goodwin, 1987). They focus on analyses of general mobility trends and on specific policy relevant issues. The following list is an overview of the various topics covered:

* Family life cycle changes and consequences for public transport (Goodwin, 1987)
* Changes in work hours and the consequences for mobility (BGC, 1988c; Kitamura 1988b)
* Residential relocation and mobility (Kitamura, 1988b)
* Mode substitution and trip-generation (van der Mede & Visser, 1987; BGC, 1988b)
* Occupational status and mobility (van Wissen & Meurs, 1986).

Finally, general aspects of the panel are described in Meurs, et al. (1986), Meurs & van Wissen (1987) and van der Loop (1988).

7. CONCLUSIONS

The Dutch Mobility Panel has become a true longitudinal research project. With the preparatory stages included, it has survived now for eight years, and the ninth year (1989) is planned. A large and unique data source has been created covering five years of

surveying. Despite the problems and difficulties encountered, it has shown to be useful in many respects.

The experience and literature on longitudinal analysis of travel demand has developed mainly in the eighties. Many methodological aspects were unknown at the start of the project, and a great deal has been learned that is valuable for policymaking and methodological developments.

From a specific policy point of view, the research has not completely lived up to its expectations. This is primarily the result of the lack of representativity of the panel. Moreover, the emphasis on descriptive population statistics, instead of a more causal oriented approach, turned out to be a disadvantage for the panel project. This attitude reflects the current view in favor of static models and explanations.

However, traditional planning models no longer provide adequate answers in a situation of dramatic increases in mobility, caused by structural changes in household composition, life styles, and other aspects of society. The "why" questions become increasingly important and this leads to increasing attention towards causal models that may give more insights and understanding of the determinants of mobility behavior. Only if we know the role of habits in transportation, or the importance and extent of lagged responses to external stimuli, are we able to anticipate future developments in the transportation system.

Current transportation models ignore such dynamic effects. This may well prove to be a too restrictive assumption that invalidates the outcomes of these models. In order to test the assumptions of static models, we need longitudinal data.

From a policy planning point of view, longitudinal data and methods offer two important advantages. First, they can be used to test and improve existing transportation models and theories. Second, if dynamic elements are important in travel behavior, then additional policy instruments might be found among these dynamic aspects of mobility: persistent habits, earlier experience, anticipated behavior, etc.

From a methodological viewpoint, many things have been learned about travel diaries in general that are valuable for any research using similar data: reporting errors, fatigue effects over days, etc. It is the first time that within-wave and between-wave biases have been explored jointly. Future projects can greatly benefit from the experiences with these phenomena in this project. From the start, the project had always maintained a strong methodological element. The experience with large longitudinal data in transportation is growing fast and the Dutch Mobility panel is a very valuable element in that process.

The size and costs of a project like this make it quite unlikely that comparable efforts will take place on a regular basis elsewhere. Here, it is worthwhile to recall some of the statements made in section two. A large-scale research project in a policy oriented environment can only survive if it serves multiple purposes and is flexible enough to adjust to continuously changing policy and research environments and there is a constant need for empirical policy oriented research. However, this does not imply that any panel should necessarily be a large and costly operation. For specific topics smaller longitudinal projects could be proposed: a smaller sample, smaller number of time periods, or a smaller questionnaire. These projects could greatly benefit from the experiences with the current panel.

A major task for transportation analysts with an interest in panel analysis is to test the validity of existing static models, and, where necessary, improve these models by incorporating dynamic elements into practical research for policy applications.

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