A Dynamic Analysis of Travel Demand

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ABSTRACT

A panel data set is analysed with the goal of identifying patterns of change in the use of various modes of transport. The data set, which represents a national sample of the Netherlands, is comprised of over 2000 individuals surveyed in three waves six months apart in 1984 and 1985. The data were processed in the form of categorical variables depicting use or non-use of each mode at each wave and were analysed using log-linear models. Results indicated that there were significant patterns of change for all of the modes studied. Some of these patterns were interpreted as representing seasonality, while others were interpreted as representing more fundamental adjustments in travel behavior.

1.0. OBJECTIVES

The primary objective of the reported research was to identify whether or not there were systematic patterns of change in the use of transport modes in the Netherlands over a one-year period from March 1984 through March 1985. During this time there was a nationwide increase in public transport fares (on April 1, 1984). Consequently, the focus of the analysis was on the use of bus-tram-metro services (considered together as one mode) and, where possible, on the use of train services. However, trends in public transport usage were placed in the context of trends in the usage of other modes of transport, particularly car and bicycle (the latter mode being an important travel option in the Netherlands).

Such a primary objective is common in the conduct of research supporting policy formulation and evaluation in transportation planning. However, a rather unique panel data base was collected for the present research. A number of authors have recently demonstrated that improved understanding of travel behavior can be achieved through the use of panel data (e.g., Clarke et. al., 1982; Daganzo and Sheffi, 1982; Johnson and Hensher, 1982; Koeppel and Hartgen, 1983; Goodwin and Layzell, 1985; Hensher and Wrigley, 1985), but techniques for analyzing panel data are not well known in the field of transportation research. Those techniques that are documented in the literature are often methodologically complex and require very specific types of data. The secondary objective of the present research was to demonstrate a methodology which was easy to use and could be applied to a wide variety of types of panel data.

2.0. THE PANEL DATA

The National Mobility Panel of the Netherlands was instituted in 1984 for a four-year experimental period. The goal of the Panel is to support the study of changes in the mobility of the Dutch population over time. An extensive description of the Panel is provided in J. Golob et al. (1985); motivations for its development are discussed in Baanders and Slootman (1982).

The panel sample is household-based and stratified by life cycle group, income and community type. The sample is clustered in twenty communities spread throughout the Netherlands. To date, there have been three waves of data collection: March 1984, September-October 1984 and March 1985. Each wave has involved a household questionnaire and separate questionnaires and travel diaries for all household members over twelve years of age. The travel diaries were for seven-day periods, with additional seven-day retrospective recordings of train trips. Potential biases in response in such a multi-day travel diary are explored in Golob and Meurs (1985), and the methodology used in the present research was specifically designed to detect changes in patterns of mode use which should be unbiased.

The sample size for the first wave of the panel was 1764 households comprising 3863 individuals. Of these original households, 1031 have remained in the panel for all three waves. (Replacements have been made at each of the second and third waves so that the original size is approximately maintained.) The 2274 individuals in the 1031 households in all three waves make up the sample for the present research. The sample is weighted so that it is representative of the general population of the Netherlands.

For the present research, the panel data were processed in a specific manner. Each respondent's travel diary was examined for each panel wave to determine whether or not that person was a user of a specific mode of transport. If the mode was used at all during the period of the diary, the person was classified as a user. With three panel waves the turnover table for each mode involves eight cells, as defined in Table 1. Separate tables were constructed for the four modes, "btm" (bus-tram-metro), car, bicycle and train, and for certain mode-purpose combinations (such as use of "btm" for work trips). In addition, separate turnover tables were constructed for each population segment (such as "12-18 years old") so that comparisons could be made among segments (such as age groups). The total-sample turnover tables for the four modes are exhibited in Table 2.

	Mode Use (0 = no/1 = yes)			
Turnover Cell	Wave 1	Wave 2	Wave 3	Description
1	0	0	0	never use the mode
2	0	1	0	use only for wave 2
3	1	0	0	quit after wave 1
4	1	1	0	quit after wave 2
5	0	0	1	begin after wave 2
6	0	1	1	begin after wave 1
7	1	0	1	quit only for wave 2
8	1	1	1	always use the mode

Table 1: Definition of a Turnover Table of Mode Use for Three Panel Waves

Since only the dichotomous use/non-use variable is required at each point in time, these turnover tables could be generated using survey data collections which are simpler and easier to use than travel diaries (such a technique was used by Smart, 1984). In any event the time frame for measuring usage (here, seven days for all modes except train, and fourteen days for train) must be long enough to reduce unwanted influences of day-to-day variations in travel behavior.

The turnovers for each of the four modes were analysed independently. Consequently, the present research is limited in its ability to provide evidence regarding substitutions among modes. Further analyses of the panel data set are reported in Bureau Goudappel Coffeng (1985), Meurs and Klok (1985) and Van Wissen and Zondag (1985). In certain of these analyses inter-dependencies between uses of different modes were investigated.

Cell in Turnover Table	Frequencies			
	BTM	Train	Car	Bicycle
1. Never use the mode (000)	1,466	1,791	122	472
2. Use only for wave 2 (010)	125	73	51	85
3. Quit after wave 1 (100)	165	84	64	110
4. Quit after wave 2 (110)	53	43	117	140
5. Begin after wave 2 (001)	103	87	41	78
6. Begin after wave 1 (011)	63	58	116	107
7. Quit only for wave 2 (101)	58	31	122	88
8. Always use the mode (111)	241	105	1,640	1,193

Table 2: Turnover Data - Weighted Sample of Panel Respondents for Waves 1, 2 and 3 (Spring 1984, Autumn 1984 and Spring 1985, Respectively)

3.0. ANALYSIS METHODOLOGY

3.1 The Log-Linear Models

The turnover tables were analysed by means of log-linear models. Such models are used to decompose contingency tables into components of a particular probability process, the objective being to identify a logical structure for the table. The name "log-linear" derives from the use of logarithmic transformations to convert multiplicative combinations of variables to linear combinations. Error terms are assumed to be Poisson-distributed because the underlying probability processes involve counts of occurrences within the cells of a table. Log-linear models are commonly used in both the social and physical sciences and are described in detail in references such as Nelder and Wedderburn (1972), Bishop, et al. (1975)

and Goodman (1978). The present methodology is an extension of that presented in Golob, et al. (1985).

The data in any turnover table can be perfectly described by a log-linear model in which there are as many variables as there are cells in the table. Such models, called saturated models, are not used in the present analyses because there is no way to test how well the model describes the data overall (that is, how well the model "fits"). With models in which there are fewer variables than cells in the turnover table, chi-square values can be calculated which measure the degree to which the model's description deviates from the observed occurrences. The hypothesis that the model does not fit can then be subjected to a chi-square test with degrees-of-freedom equal to the number of cells in the table minus the number of variables in the model. Such tests are provided for all log-linear models estimated and results are documented for the $p = .05$ confidence level. (Because the tests concern the "badness-of-fit" of the models, the $p = .05$ level is a stricter test of model performance than the $p = .01$ level.)

Some of the variables in the models are "control variables". These provide a means of standardising the different tables so that comparisons can be made among them. They also provide a base from which change can be measured. The remaining variables in each model represent specific hypotheses regarding a process of change. A coefficient is estimated for each of these variables, together with a standard error of estimate which is used to establish a z-value for the coefficient. These z-values (usually considered to be normally distributed) are used to test whether a coefficient is significantly different from zero at the $p = .05$ confidence level (one-tailed tests are typically used because the sign of each coefficient is anticipated). In this manner each log-linear model represents a test of a specific process of change over time in the use of a mode.

The GLIM (Generalised Linear Interactive Modeling) computer program (Nelder and Weddenburn, 1972; Baker and Nelder, 1978; McCullagh and Nelder, 1983) was used in implementing the models. Many other commonly-used statistical analysis program packages also include log-linear analyses that can be used to implement the methodology.

3.2 Model Specifications

The variables employed in all of the models reported here were selected from a common set of nine. However, no more than seven of these variables are used in a single model, and quite often only four or five are needed to describe the total turnovers for a specific mode or the turnovers exhibited by a particular population segment. There are four control variables and five variables representing change hypotheses. A typical log-linear model is specified using three or all four of the control variables, and up to three of the hypotheses variables. Variable selection was conducted in the usual manner: the subset of variables with the greatest explanatory power was chosen, and generally only variables with statistically significant coefficients were kept in the final models.

One control variable is always the grand mean of the turnover table; this can be considered the model constant. The remaining three control variables are defined in Table 3a.

The two control variables "stayers I: non-users" and "stayers II: users" reflect the fact that persons who display no changes in use over the three waves provide no information about change processes. These two control variables assure that the two cells do not affect the tests of the change hypotheses. The remaining control variable, "usage level at wave 2", simply establishes a base from which change can be measured; such a variable will be significant whenever the usage level at wave 2 for any mode differs significantly from a 50%/50% split.

Cell in Turnover Table	Defining Contrasts		
	Stayers I: Non-Users	Stayers II: Users	Usage at Wave 2
1. Never use the mode (000)	+1	0	−1
2. Use only for wave 2 (010)	−1	−1	+1
3. Quit after wave 1 (100)	−1	−1	−1
4. Quit after wave 2 (110)	−1	−1	+1
5. Begin after wave 2 (001)	−1	−1	−1
6. Begin after wave 1 (011)	−1	−1	+1
7. Quit only for wave 2 (101)	−1	−1	−1
8. Always use the mode (111)	0	+1	+1

<u>Table 3a:</u> Specification of the Control Variables in the Log-Linear Models of Mode Turnovers

The five variables representing specific hypothesis in change in mode use are defined in Table 3b.

Cell in Turnover Table	Defining Contrasts				
	General Trend	Season-ality	Timing of Decrease	Timing of Increase	Time Scale of Usage
1. Never use the mode (000)	0	0	0	0	+1
2. Use only for wave 2 (010)	0	+2	0	0	−1
3. Quit after wave 1 (100)	−1	−1	+1	0	+1
4. Quit after wave 2 (110)	−1	+1	−1	0	+1
5. Begin after wave 2 (001)	+1	−1	0	−1	+1
6. Begin after wave 1 (011)	+1	+1	0	+1	+1
7. Quit only for wave 2 (101)	0	−2	0	0	−1
8. Always use the mode (111)	0	0	0	0	+1

<u>Table 3b:</u> Specification of Change-Hypothesis Variables in the Log-Linear Models of Mode Turnovers.

The first change-hypothesis variable, "general trend" contrasts a steady increase in usage (cells 5 and 6 which count occurrences of beginning use) against a steady decrease in usage (cells 3 and 4, which count occurrences of quitting use). This variable thus represents a linear trend in increasing usage (positive sign) or decreasing usage (negative sign) over the time period of the three waves. Any biases over time in the underreporting of travel can be expected to be reflected in linear trend variables with negative signs (Golob and Meurs, 1985).

The second change-hypothesis variable, "seasonality" measures the extent to which the usage level for the second wave (autumn) deviates from a linear interpolation of the first and third (spring and spring) usage levels. The derivation of this variable is shown in Table 4; it can be defined as the usage level at wave 2 minus the mean of the usage levels at waves 1 and 3.

	Contrasts Defining Log-Linear Variables				
Cell in Turnover Table	Usage at Wave 1	Usage at Wave 2	Usage at Wave 3	Usage: 1/2 x (Wave 1 + + Wave 3)	Seasonality: Wave 2 - 1/2 x (Wave 1 + Wave 3)
1. Never use the mode (000)	-1	-1	-1	-1	0
2. Use only for wave 2 (010)	-1	+1	-1	-1	+2
3. Quit after wave 1 (100)	+1	-1	-1	0	-1
4. Quit after wave 2 (110)	+1	+1	-1	0	+1
5. Begin after wave 2 (001)	-1	-1	+1	0	-1
6. Begin after wave 1 (011)	-1	+1	+1	0	+1
7. Quit only for wave 2 (101)	-+1	-1	+1	+1	-2
8. Always use the mode (111)	+1	+1	+1	+1	0

Table 4: Derivation of the "Seasonality" Variable in the Log-Linear Models of Turnovers in Mode Use.

When this variable is found to be significant with a positive sign, it shows that second wave (autumn) demand is significantly above that predicted by an interpolation of first and third wave (spring to spring) demand, taking into account non-seasonal changes in usage between the waves. The seasonality variable can also be viewed as contrasting the special events in usage at wave 2 (010 = cell 2 = use only at wave 2, and 101 = cell 7 = quit use only at wave 2) against similar special events in usage at waves 1 and 2 combined (cells 4, 6, 3 and 5).

The third change-hypothesis variable is entitled "timing of decrease." This variable simply contrasts dropping of use after wave 1 (cell 3) with dropping of use after wave 2 (cell 4). If there are any factors which cause a greater decrease in use from wave 1 to wave 2 than from wave 2 to wave 3, then this timing variable should be significant with a positive sign. A necessary condition for a measurable effect on "btm" demand of the April 1, 1984 public transport fare increase is that the timing variable be estimated to be significantly greater than zero. (However, it is impossible with these data to separate the fare effect from other external influences which occurred within the same time period.)

The fourth change-hypothesis variable shown in Table 3b is entitled "timing of increase". This is analogous to the previous "timing of decrease" variable in that it contrasts beginning of use after wave 1 (cell 6) with beginning of use after wave 2 (cell 5). If use of a mode is positively influenced by conditions which occur in the wave 1 to wave 2 period, such as the April 1, 1984 fare increase, then this variable can be expected to be significant with a positive sign. This would indicate that users have switched to the mode in question from the mode or modes negatively influenced by the conditions in the wave 1 to wave 2 period.

The fifth and final change-hypothesis variable is entitled "time scale of usage". This variable can be thought of as inertia: The time scale of usage of some modes may be such that a unique usage pattern at only the second wave (cells 2 and 7) is relatively rare. Rather, usage in wave 2 should be similar to either usage in wave 1 or usage in wave 3, or both. In other words, unique adjustments in use at wave 2 are rare if this variable is found to be significant with a positive sign.

All of the change hypotheses variables, with the exception of the linear trend variable, should be unbiased with respect to the under-reporting of trips from wave to wave. This assumption is based on results documented in Golob and Meurs (1985), which showed linear relationships in the under-reporting of trips over seven-day diary periods. It is unknown as to whether such reporting biases affect comparisons over panel waves. In any case, the greatest levels of bias were found for walking trips, which are not analysed here, and the least levels of bias were found for "btm" trips, which are a main focus here (Golob and Meurs, 1985).

4.0. TURNOVERS IN BUS-TRAM-METRO (BTM) USE

4.1 Total Sample

All four of the control variables of Table 3a and three of the change-hypothesis variables of Table 3b were found to be effective in describing turnovers in "btm" use. The change-hypotheses variables included were "general trend", "seasonality" and "timing of decrease". The overall descriptive power of the model was very good. The chi-square measure of model deviance (equivalent to minus two times the log-likelihood ratio) was 0.0388 with one degree-of-freedom. The hypothesis that the model does not fit was thus firmly rejected (as the critical chi-square value with one degree-of-freedom is 3.84). The variable coefficients and associated z-statistics are listed in Table 5.

Variable	Coefficient	Z-statistic
Control variables		
Grand mean	5.74	206.9*
Stayers I: non-users	0.672	3.77*
Stayers II: users	0.615	3.27*
Usage level at wave 2	-0.874	-4.89*
Change hypotheses		
General trend in use	-0.0747	-1.32
Seasonality: wave 2 versus 1 and 3	0.627	5.62*
Timing of decrease: wave 1 to 2 versus 2 to 3	0.324	2.88*

Table 5: Log-Linear Model of Turnovers in BTM use (* = Variable Coefficients Significantly Different from Zero at p = .05 Level in One-Tailed Tests)

The strongest of the change variables is seasonality. The implication is that there was abnormally high "btm" use during the period of the second panel wave (mainly late September through early October 1984). The timing variable is also strong. The implication is that there was significantly more reduction in usage from wave 1 to wave 2 than can be predicted on the basis of all other variables, including a steady decrease over all three waves. This third change variable, general grend, is negative (indicating decrease rather than increase) but is not quite significant at the p = .05 confidence level (the critical value being -1.65). While this variable is not crucial to the fit of the present model, it is included in order to provide a basis for comparisons among models of "btm" turnovers for different trip purposes and population segmentations.

4.2 Trip Purposes

In order to gain a better understanding of changes in "btm" usage, log-linear models were estimated for turnovers in "btm" usage for five specific trip purposes: (1) work, (2) school, (3) shopping and personal business, (4) social-recreational and (5) other purposes. The overall descriptive powers of these five models are listed in Table 6. The models were all significant but differed in terms of the change-hypothesis variables needed to describe turnovers.

Trip Purposes	Chi-Square Test of Model Fit		
	Number of Variables	(-2) Log-Likelihood Ratio	Degrees of Freedom
Work	6	0.1588*	2
School	6	4.017*	2
Shopping and personal business	5	3.498*	3
Social-recreational	5	2.847*	3
Other purposes	6	1.314*	2
Total sample	7	0.03882*	1

Table 6: Goodness-of-Fit Statistics for Log-Linear Models of Turnovers in BTM use for Specific Trip Purpose (* = Hypothesis of Poor Fit Rejected at p = .05 Level → Model Significant)

The estimation results for the model of "btm" turnovers for work trips are shown in Table 7. Seasonality is quite strong, and there is a weak but significant downward trend in "btm" work-trip use. Importantly, the timing variable is insignificant, which indicates that no short-term effect of the April 1, 1984 fare increase is apparent for work trips. Of course, part or all of the general downward trend might be due to fare changes (for example, through the gradual reduction of season ticket holding), but the trend variable is weak in any case.

The results for school trips are shown in Table 8. (In the turnover analysis for school trips, only persons making school trips by any mode in all three panel waves were included in order to avoid cohort effects involving children leaving school during the course of the three waves.) There was no descriptive power in the

Variable	Coefficient	Z-statistic
Control Variables		
Grand mean	4.75	75.6*
Stayers I: non-users	1.06	3.43*
Stayers II: users	0.859	2.40*
Usage level at wave 2	-1.85	-5.73*
Change hypotheses		
General trend in use	-0.187	-1.72*
Seasonality: wave 2 versus 1 and 3	1.15	5.12*
Timing of decrease: wave 1 to 2 versus 2 to 3	(excluded)	-

Table 7: Log-Linear Model of Turnovers in BTM Use for Work Trips (* = Variable Coefficients Significantly Different from Zero at p = .05 Level in One-Tailed Tests)

Variable	Coefficient	Z-statistic
Control variables		
Grand mean	3.60	22.4*
Stayers I: non-users	1.42	13.2*
Stayers II: users	(excluded)	-
Usage level at wave 2	-0.328	-2.88*
Change hypotheses		
General trend in use	(excluded)	-
Seasonality: wave 2 versus 1 and 3	0.291	2.05*
Timing of decrease: wave 1 to 2 versus 2 to 3	0.530	2.28*
Time scale of usage: wave 2 similar to either wave 1 or 3	0.418	2.54*

Table 8: Log-Linear Model of Turnovers in BTM Use for School Trips by those Persons Making School Trips in all Three Waves (n = 427) (* = Variable Coefficients Significantly Different from Zero at p = .05 Confidence Level in One-Tailed Test)

general trend variable, which was thus excluded from the model. Seasonality was relatively weak, but significant. The two strongest change variables were timing of decrease, which indicates a possible strong fare-increase effect, and time scale of usage. The time scale variable suggests that choice of "btm" for school trips involves a longer-term decision process than does choice of "btm" for non-school purposes.

The results for shopping and personal business trips are shown in Table 9. Of the change-hypothesis variables, only seasonality was found to have descriptive power. There appear to be no other systematic changes in the usage of "btm" for shopping purposes.

Variable	Coefficient	Z-statistic
Control variables		
Grand mean	5.08	93.7*
Stayers I: non-users	0.747	3.92*
Stayers II: users	0.482	2.11*
Usage level at wave 2	-1.73	-8.93*
Change hypotheses		
General trend in use	(excluded)	-
Seasonality: wave 2 versus 1 and 3	1.18	8.72*
Timing of decrease: wave 1 to 2 versus 2 to 3	(excluded)	-

Table 9: Log-Linear Model of Turnovers in BTM use for Shopping and Personal Business Trips (* = Variable Coefficients Significantly Different from Zero at p = .05 Level in One Tailed Tests)

The results for social-recreational use of "btm" are shown in Table 10. Both seasonality and timing of decrease are strong, the general trend variable is weak. Use of "btm" for social-recreational purposes falls off strongly between waves 1 and 2.

Variable	Coefficient	Z-statistic
Control Variables		
Grand mean	5.23	118.2*
Stayers I: non-users	1.42	26.8*
Stayers II: users	(excluded)	-
Usage level at wave 2	-0.893	-12.1*
Change hypotheses		
General trend in use	(excluded)	-
Seasonality: wave 2 versus 1 and 3	0.677	10.9*
Timing of decrease: wave 1 to 2 versus 2 to 3	0.619	5.22*

Table 10: Log-Linear Model of Turnovers in BTM Use for Social-Recreational Trips (* = Variable Coefficients Significantly Different From Zero at p = .05 Level in One-Tailed Tests)

Finally, the results for other trip purposes (hauling of goods, serve-passenger and the "other" category in the trip diaries) are shown in Table 11.

These results are similar to those in the previous table for social-recreational trips. It appears that use of "btm" for the most discretionary purposes, social-recreational and "other", is most influenced (in a negative way) by conditions during the spring 1984 to autumn 1984 time period.

Variable	Coefficient	Z-statistic
Control variables		
Grand mean	4.51	47.9*
Stayers I: non-users	2.09	6.61*
Stayers II: users	-0.848	-2.32*
Usage level at wave 2	-1.024	-3.31*
Change hypotheses		
General trend in use	(excluded)	-
Seasonality: wave 2 versus 1 and 3	0.929	4.78*
Timing of decrease: wave 1 to 2 versus 2 to 3	0.896	4.80*

Table 11: Log-Linear Model of Turnovers in BTM Use for other Trip Purposes (* = Variable Coefficients Significantly Different from Zero at p = .05 Level in One-Tailed Tests)

4.3 Population Segments

The log-linear model of "btm" turnovers was estimated separately for forty-one different population segments for eleven segmentation criteria. The model fit can be rejected for only two of these forty-one segments. The salient results for the model estimations are shown in Table 12. The principal interest is in the significance levels of the three variables representing change hypotheses. Thus, in Table 12, only the signs are given for significant variables.

There is substantial heterogeneity among the segments, as shown in Table 12. This indicates that the factors responsible for the changes in "btm" usage during the spring 1984 to spring 1985 period have affected population groups differently. This is to be expected if such factors include public transport fare increases. It can be shown that many of the differential effects indicated by the results of Table 12 are consistent with fare increases as partial causes of decrease in "btm" usage.

It can be expected that increases in the monetary costs of travel will affect lower-income households to a greater extent than higher-income households. Indeed, a comparison of the income segments in Table 12 reveals that the two lower income segments have timing variables (decrease in usage over the wave 1 to wave 2 period, rather than the wave 2 to wave 3 period) which are significant, while the two higher income classes do not. Similarly, zero-car households also exhibit a significant timing component of decrease in "btm" use.

The fare increases on April 1, 1984 were proportionally greater for children than for other user groups. Indeed, among the age-group segments, only 12-18 years olds exhibit a significant timing component of change. This is also reflected in the children segment of the position-in-the-household segmentation. The significant timing component found for the non-worker segment of the employment-status segmentation might reflect effects for both children and low-income groups.

Population Segment	Change Hypothesis: General Trend	Seasonality	Timing of Decrease
Life cycle			
1. Couples 35 yrs	NS	NS	+
2. All children 12 yrs	NS	+	NS
3. 1 child 12-18 yrs	NS	+	NS
4. Couples 35-64	NS	+	NS
5. Retirees	(MNS)	(MNS)	(MNS)
6. Singles 65 yrs	NS	+	NS
Life cycle (2)			
1. Single-parent households	-	NS	NS
2. other households	NS	+	+
Household income			
1. f 0-17,000	NS	+	+
2. f 17-24,000	NS	+	+
3. f 24-38,000	NS	+	NS
4. f 38,000+	-	+	NS
Residential location			
1. Urban centers (Amsterdam, Rotterdam)	NS	NS	NS
2. Large cities (secondary centers)	NS	+	+
3. Tertiary centers	NS	+	NS
4. Commuter cities	NS	+	NS
5. Rural communities	-	+	+
Age			
1. 12-18	NS	NS	+
2. 19-25	NS	+	NS
3. 26-45	NS	+	NS
4. 46-59f/64m	-	+	NS
5. 60+ f/65+ m	(MNS)	(MNS)	(MNS)
Sex			
1. Male	NS	+	NS
2. Female	-	+	+
Household car ownership			
1. 0 cars	NS	NS	+
2. 1 car	-	+	NS
3. 2+ cars	NS	+	NS
Employment status			
1. Non-worker	NS	+	+
2. Part-time worker	-	NS	NS
3. Full-time worker	NS	+	NS
Household size			
1. 1	-	NS	NS
2. 2	NS	+	+
3. 3	NS	+	NS
4. 4	NS	+	NS
5. 5+	NS	NS	NS
Position in the household			
1. Male head	NS	+	NS
2. Non-working female	NS	+	NS
3. Working female	-	+	NS
4. Child	NS	NS	+
Driving license			
1. Non-driver	NS	+	NS
2. Driver	NS	+	-

Table 12: Significance Levels of Change-Hypothesis Variables in Log-Linear Models for Population Segments - BTM Turnovers (+ = Variable Significant with Positive Sign; - = Variable Significant with Negative Sign; NS = Variable not Significant; (MNS) = Model not Significant for Segment)

There are other segments which also exhibit significant timing components of change in usage. The life cycle segment defined as couples less than 35 years old with no children at home also drops "btm" usage significantly after wave 1, and this segment is also part of the household-size-2 segment. In addition, females in general exhibit a signficant timing component of change, as do residents of large cities and rural communities.

Finally, a few segments exhibit a steady decrease in usage. This could reveal longer-term adjustments to fare increases (for example, in terms of not renewing season tickets or increasing household car ownership) or it might indicate the presence of causal factors other than fare increases (for example, income effects, job relocations, service-level effects, or changes in working hours). These segments with significant steady decreases in usage over all three waves include: single-parent households, high-income households, households residing in rural communities, the 46 to retirement age group, females, one-car households, part-time workers, singles (including retired singles) and working female heads-of-household.

5.0. TURNOVERS IN CAR USE

5.1 Total Sample

The specification of the log-linear model describing turnovers in car use is identical to that for "btm" turnovers. Both car-passenger and car-driver modes are considered together in a single turnover table (shown in Table 2). As in the case of "btm," the fit of the model of car turnovers is exceptionally good: the chi-square deviance statistic is 0.0413 with one degree-of-freedom.

The parameter estimates for this model are shown in Table 13. All of the variables are significant at the p = .05 level in one-tailed tests of significance.

Of the three variables reflecting specific hypotheses of change in usage, the strongest is seasonality. Apparently, there was abnormally low car use in late September - early October 1984. There is also a weak, but significant, general downward trend in car use over all three waves.

Variable	Coefficient	Z-statistic
Control Variables		
Grand mean	5.52	156.7*
Stayers I: non-users	0.758	3.53*
Stayers II: users	0.408	2.07*
Usage level at wave 2	1.47	7.40*
Change hypotheses		
General trend in use	-0.112	-1.90*
Seasonality: wave 2 versus 1 and 3	-0.958	-7.79*
timing of decrease: wave 1 to 2 versus 2 to 3	0.216	1.82*

Table 13: Log-Linear Model of Turnovers in Car use (* = Variable Coefficients Significantly Different from Zero at p = .05 Level in One-Tailed Tests)

Importantly, there is a relatively weak, but just significant, timing component of change, indicating greater decrease in car use from wave 1 to wave 2 than from wave 2 to wave 3. While this variable is weaker for car use than for "btm" use (Table 5), it shows that there were probably some changes over the spring 1984 - autumn 1984 period which were unrelated to the April 1, 1984 public transport fare increase.

5.2 Population Segments

Results from estimation of the model of car turnovers for the forty-one population segments are shown in Table 14. The model could be rejected for only three of these segments: residents of the largest urban centers, members of two-person households and members of four-person households. Insights into

Population Segment	Change Hypothesis		
	General Trend	Seasonality	Timing of Decrease
Life Cycle			
1. Couples 35 yrs	NS	-	+
2. All children 12 yrs	NS	-	NS
3. 1 child 12-18 yrs	-	-	NS
4. Couples 35-64	+	-	NS
5. Retirees	-	-	+
6. Singles 65 yrs	NS	-	NS
Life cycle (2)			
1. Single-parent households	NS	NS	NS
2. Other households	-	-	+
Household income			
1. f 0-17,000	-	-	NS
2. f 17-24,000	NS	-	+
3. f 24-38,000	NS	-	NS
4. f 38,000+	NS	-	NS
Residential location			
1. Urban centers (Amsterdam, Rotterdam)	(MNS)	(MNS)	(MNS)
2. Large cities (secondary centers)	-	-	NS
3. Tertiary centers	NS	-	NS
4. Commuter cities	NS	-	NS
5. Rural communities	NS	-	NS
Age			
1. 12-18	-	-	NS
2. 19-25	NS	-	NS
3. 26-45	NS	-	NS
4. 46-59f/64m	NS	-	NS
5. 60+ f/65+ m	-	-	+
Sex			
1. Male	-	-	+
2. Female	NS	-	NS
Household car ownership			
1. 0 cars	NS	-	+
2. 1 car	-	-	NS
3. 2+ cars	-	-	NS
Employment status			
1. Non-worker	-	-	+
2. Part-time worker	NS	-	NS
3. Full-time worker	NS	-	NS
Household size			
1. 1	NS	NS	NS
2. 2	(MNS)	(MNS)	(MNS)
3. 3	NS	-	NS
4. 4	(MNS)	(MNS)	(MNS)
5. 5+	-	-	+
Position in the household			
1. Male head	NS	-	NS
2. Non-working female	NS	-	+
3. Working female	NS	-	NS
4. Child	-	-	NS
Driving license			
1. Non-driver	-	-	NS
2. Driver	NS	-	NS

Table 14: Significance Levels of Change-Hypothesis Variables in Log-Linear Models for Population Segments - Car Turnovers (+ = Variable Significant with Positive Sign; - = Variable Significant with Negative Sign; NS = Variable not Significant; (MNS) = Model not Significant for Segment)

possible causes of change for the remaining segments can be gained by comparing the results in Table 14 with those in Table 12 for "btm."

Timing influences on both car and "btm" use are present for the life-cycle segment of couples less than 35 years old with no children at home. Similarly, the second-lowest income class exhibits timing change for both car and "btm," as do members of zero-car households and non-workers. Thus, it can be concluded that some of the decrease in "btm" use between waves 1 and 2 for these segments is due to factors affecting both "btm" and car demand.

However, the timing effect present in Table 12 for children, low-income households, females, drivers and residents of large cities and rural communities is not matched by an analogous decrease in car use. Rather, males, non-working females and retired persons exhibit timing effects in their decreases in car usage only.

Due to the research focus on bus-train-metro services, no models were estimated for separate trip purposes for car, and the same is true for the bicycle mode described in the next section. These trip-purpose analyses represent a potentially useful extension of the reported research.

6.0. TURNOVERS IN BICYCLE USE

6.1 Total Sample

Six variables were required to describe turnovers in bicycle use for the total sample: three of the four control variables, plus the change-hypothesis variables "general trend in use", "timing of decrease" and "timing of increase" (all defined in Table 3b). The fit of the model is good, with a deviance chi-square statistic of 5.473 with two degrees-of-freedom (the critical value for rejection of the model being 5.991 with two degrees-of-freedom). However, the model deviance is relatively higher for bicycle than for "btm" and car (adjusting for degrees-of-freedom), indicating that there are more differences among persons in terms of changes in bicycle use.

The variable coefficients and associated z-statistics for the bicycle turnovers model are listed in Table 15.

Variable	Coefficient	Z-statistic
Control variables		
Grand mean	5.948	261.5*
Stayers I: non-users	0.209	5.97*
Stayers II: users	1.136	40.3*
Usage level at wave 2	(excluded)	-
Change hypotheses		
General trend in use	-0.164	-3.24*
Seasonality: wave 2 versus 1 and 3	(excluded)	-
Timing of decrease: waves 1 to 2 versus 2 to 3	-0.127	-1.95*
Timing of increase: waves 1 to 2 versus 2 to 3	0.170	2.21*

Table 15: Log-Linear Model of Turnovers in Bicycle Use (* = Variable Coefficients Significantly Different from Zero at p = .05 Level in One-Tailed Tests)

The strongest change variables are "general trend" (which indicates a downward trend in bicycle usage) and "timing of increase." The sign on timing of increase indicates that there is a greater increase in bicycle use between the first and second waves than between the second and third waves. The third change variable, "timing of decrease," has a negative sign, which indicates that there is a greater decrease in bicycle use between the second and third waves than between the first and second.

These results indicate that bicycle usage, while generally decreasing, has changed in a pattern which is opposite to that of "btm" changes. It appears that there was movement from "btm" to bicycle in the spring to autumn 1984 time period.

6.2 <u>Population Segments</u>

Results from estimations of the bicycle turnover model for population segments are shown in Table 16. The model fit was rejected for ten of the forty-one segments. Once again this indicates considerable heterogeneity in bicycle usage patterns.

Of particular interest are those segments for which bicycle use remains relatively constant over the three waves. These are identified by non-significant coefficients for all of the change variables. They are: couples 35-64 years old with no child at home; single parent households; persons from two-or-more-car households; full-time workers; persons from the largest households; and children. All other segments displayed some significant changes in bicycle use which can be useful in further investigations of travel demand.

Of further interest are those population segments which exhibited increases in bicycle use during the wave 1 to wave 2 period. These are households with at least one child 12-18 years old, residents of large cities, 12-18 year olds and 26-45 year olds, males, members of one-car households, male heads-of-household, and drivers.

7.0. TURNOVERS IN TRAIN USE

7.1 Total sample

Only five variables were needed to describe train turnovers: three control variables and two change-hypotheses variables. Once again, a very good model fit was achieved, with a deviance chi-square statistic of 3.119 with three degrees-of-freedom. (The critical value for rejection of such a model with three degrees-of-freedom is 7.815.) The model parameter estimates are shown in Table 17.

	Change Hypothesis		
Population Segment	General Trend	Timing of Decrease	Timing of Increase
Life cycle			
1. Couples 35 yrs	-	-	NS
2. All children 12 yrs	(MNS)	(MNS)	(MNS)
3. 1 child 12-18 yrs	-	NS	+
4. Couples 35-64	NS	NS	NS
5. Retirees	-	NS	NS
6. Singles 65 yrs	(MNS)	(MNS)	(MNS)
Life cycle (2)			
1. Single-parent households	NS	NS	NS
2. Other households	-	-	+
Household income			
1. f 0-17,000	(MNS)	(MNS)	(MNS)
2. f 17-24,000	NS	-	NS
3. f 24-38,000	-	NS	+
4. f 38,000+	-	NS	NS
Residential location			
1. Urban centers (Amsterdam, Rotterdam)	(MNS)	(MNS)	(MNS)
2. Large cities (secondary centers)	-	-	+
3. Tertiary centers	(MNS)	(MNS)	(MNS)
4. Commuter cities	-	NS	NS
5. Rural communities	NS	-	NS
Age			
1. 12-18	NS	NS	+
2. 19-25	(MNS)	(MNS)	(MNS)
3. 26-45	NS	NS	+
4. 46-59f/64m	-	+	NS
5. 60+ f/65+ m	-	NS	NS
Sex			
1. Male	-	NS	+
2. Female	(MNS)	(MNS)	(MNS)
Household car ownership			
1. 0 cars	-	-	NS
2. 1 car	-	-	+
3. 2+ cars	NS	NS	NS
Employment status			
1. Non-worker	(MNS)	(MNS)	(MNS)
2. Part-time worker	NS	-	NS
3. Full-time worker	NS	NS	NS
Household size			
1. 1	-	-	NS
2. 2	-	-	NS
3. 3	-	NS	NS
4. 4	(MNS)	(MNS)	(MNS)
5. 5+	NS	NS	NS
Position in the household			
1. Male head	NS	NS	+
2. Non-working female	(MNS)	(MNS)	(MNS)
3. Working female	(MNS)	(MNS)	(MNS)
4. Child	NS	NS	NS
Driving license			
1. Non-driver	NS	-	NS
2. Driver	-	NS	+

Table 16: Significance Levels of Change-Hypothesis Variables in Log-Linear Models for Population Segments - Bicycle Turnovers (+ = Variable Significant with Positive Sign; - = Variable Significant with Negative Sign; NS = Variable not Significant; (MNS) = Model not Significant for Segment)

Variable	Coefficient	Z-statistic
Control variables		
Grand mean	5.28	83.5*
Stayers I: non-users	1.24	25.6*
Stayers II: users	(excluded)	-
Usage level at wave 2	-0.817	-13.0*
Change hypotheses		
General trend in use	(excluded)	-
Seasonality: wave 2 versus 1 and 3	0.594	9.73*
Timing of decrease:		
waves 1 to 2 versus 2 to 3	(excluded)	-
Time scale of usage:		
Wave 2 similar to either wave 1 or 3	0.159	2.61*

Table 17: Log-Linear Model of Turnovers in Train Use (* = Variable Coefficient Significantly Different from Zero at p = .05 Level in One-Tailed Test)

The seasonality variable is the stronger of the two change variables, indicating that train usage was relatively high in late-September/early-October 1984. The time scale of usage variable indicates that choices involving train use are generally made over a period of time which typically spans more than one panel wave.

While there is no general trend variable with descriptive power for the total sample, some population segments were found to exhibit trends in train use, as explored in the next section of this report. However, neither the total sample nor any population segment was found to exhibit turnover patterns which were consistent with the timing variable designed to detect possible influences of the April 1984 fare increase.

7.2 Population Segments

A summary of the parameter estimates for the train turnover models for population segments is provided in Table 18. A significant model was established for each of the forty-one segments. The summary table shows that there is considerable heterogeneity among the segments in terms of patterns of change in train usage.

Regarding seasonality, most of the segments display a positive sign on the variable (indicating higher use in the autumn), but three segments displayed an opposite negative sign (indicating lower use in the autumn). These three were retirees, residents of the largest urban cities, and females 60 years or older and males 65 years or older (some of whom might reside in non-retired households).

A general trend effect was found for only five segments, all of which displayed increasing train use (a positive sign on the variable). These segments were couples over 35 years with no children at home, singles (repeated in the household size segmentation), working females, and children (essentially duplicated in the age and position-in-the-household segmentations).

Sample sizes were deemed to be insufficient to allow analyses of separate trip purposes for the train mode.

8.0. SUMMARY OF THE REVEALED PATTERNS OF CHANGE

Measured in terms of the numbers of persons who use "btm" (bus-tram-metro) during a week-long period, "btm" use was down about ten percent from wave 1 (spring 1984) to wave 3 (spring 1985). The drop in "btm" use from wave 1 to wave 2 was about 7%, but it was determined that wave 2 (late September-early October 1984) exhibited a seasonal peak in use. Thus, the drop in "btm" use from wave 1 to wave 2 is understated due to seasonal factors. Most of the approximately 10 percent drop in use between spring 1984 and spring 1985 can be attributed to conditions which occurred in the March 1984 to September 1984 period.

Population Segment	Change Hypothesis: Seasonality	Time Scale of Usage	General Trend
Life cycle			
1. Couples 35 yrs	+	NS	VNI
2. All children 12 yrs	+	+	VNI
3. 1 child 12-18 yrs	+	+	VNI
4. Couples 35-64	+	NS	+
5. Retirees	-	NS	VNI
6. Singles 65 yrs	NS	NS	+
Life cycle (2)			
1. Single-parent households	+	NS	VNI
2. Other households	+	+	VNI
Household income			
1. f 0-17,000	NS	NS	VNI
2. f 17-24,000	NS	+	VNI
3. f 24-38,000	+	NS	VNI
4. f 38,000+	+	NS	VNI
Residential location			
1. Urban centers (Amsterdam, Rotterdam)	-	NS	VNI
2. Large cities (secondary centers)	+	NS	VNI
3. Tertiary centers	+	NS	VNI
4. Commuter cities	+	+	VNI
5. Rural communities	+	+	VNI
age			
1. 12-18	+	NS	VNI
2. 19-25	+	NS	VNI
3. 26-45	+	+	VNI
4. 46-59f/64m	+	NS	VNI
5. 60+ f/65+ m	-	+	VNI
Sex			
1. Male	+	+	VNI
2. Female	+	NS	VNI
Household car ownership			
1. 0 cars	+	+	VNI
2. 1 car	+	+	VNI
3. 2+ cars	+	NS	VNI
Employment status			
1. Non-worker	+	+	VNI
2. Part-time worker	+	NS	VNI
3. Full-time worker	+	NS	VNI
Household size			
1. 1	+	+	+
2. 2	NS	+	VNI
3. 3	+	NS	VNI
4. 4	+	NS	VNI
5. 5+	+	+	VNI
Position in the household			
1. Male head	+	+	VNI
2. Non-working female	+	+	VNI
3. Working female	NS	+	+
4. Child	NS	+	+
Driving license			
1. Non-driver	+	+	VNI
2. Driver	+	NS	VNI

Table 18: Significance Levels of Change-Hypothesis Variables in Log-Linear Models for Population Segments - Train Turnovers (+ = Variable Significant with Positive Sign; - = Variable Significant with Negative Sign; NS = Variable not Significant; (MNS) = Model not Significant for Segment); VNI = Variable not Included

Regarding "btm" use for different trip purposes and by different population segments, use for school, socio-recreational and other (mostly discretionary) trips fell off most strongly between wave 1 and 2. There was no change in use of "btm" for shopping and personal business trips and only a long-term slight decrease in "btm" use for work trips. The segments which exhibited the greatest decreases in "btm" usage over the wave 1 to wave 2 period were those expected to be most affected by a fare increase (for instance, lower income groups, and children for which fare increases were proportionally greater).

Car use was also down from wave 1 to wave 3, by a little over one percent. Importantly, a portion of the decrease in car use can be attributed specifically to changes which occur uniquely over the wave 1 to wave 2 period. The magnitude of this non-fare-related decrease is approximately one-third that of the overall decrease in "btm" use over the same period. Thus, it is possible that about one-third of the ten percent decrease in "btm" use could be related to conditions which affect mobility by motorised modes in general. The remaining, potentially fare-related decrease in general "btm" use is on the order of six to seven percent.

By comparing the models of "btm" and car turnovers for specific population segments, it is possible to distinguish segments with wave 1 to wave 2 decreases in only "btm" use from segments with wave 1 to wave 2 decreases in both "btm" and car use. In the former category ("btm" decreases not matched by car decreases) are children, low-income households, females, drivers (who have more choices available), and residents of certain types of communities. In the latter category (decreases in both "btm" and car use) are couples under thirty-five with no children at home, households in the second income class, zero-car households, and non-workers.

Bicycle use, while down somewhat from wave 1 to wave 3, displayed a relative increase over the wave 1 to wave 2 period which reflected the decrease in "btm" use over the same period. Such increases in bicycle use were concentrated in certain population segments.

With respect to train use, there was no general trend for the total sample, either upward or downward and no fare-effect. However, there was a strong seasonality component of change, indicating that train usage was relatively high during the wave 2 period (late September/early October 1984). There were many differences among population segments in terms of their train usage patterns. Five segments exhibited general upward trends in train use. In addition, some segments exhibited a seasonal component of use which was opposite to that for the total sample; use for these segments was abnormally down in wave 2. Such differences in changes in train usage can be useful in the development of policies to market train services.

9.0. CONCLUSIONS

The methodology was effective in identifying unambiguous patterns of change in travel demand, which demonstrated that panels can provide information not readily obtainable through analyses of cross-sectional data sets. In addition to the results for the total sample which were consistent with expectations based on external evidence, considerable information was generated concerning differences in travel behavior among population segments. This information should be useful in understanding the differential effects of fare policies and other changes which occurred during the period under study.

The methodology proved easy to use and can be readily extended to more than three panel waves. However, it does require the a priori specification of hypotheses of change so that such hypotheses can be tested as model variables. This was not difficult in the present analysis, but might require more effort when more than three waves are analysed and in situations where little is known about potential causal factors.

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REFERENCES

Baanders, A. and K.C.P. Slootman (1982). A Panel for longitudinal research into travel behaviour. In S. Carpenter and P.M. Jones, eds., Recent Advances in Travel Demand Analysis. Aldershot: Gower.

Baker, R.J. and J.A. Nelder (1978). The GLIM System, Release 3. Oxford: Numerical Algorithms Group.

Bishop, Y.M., S.E. Fienberg and P.W. Holland (1975). Discrete Multivariate Analysis: Theory and Practice. Cambridge, MA: MIT Press.

Bureau Goudappel Coffeng (1985). Analyse Longitudinaal Verplaatsingsonderzoek: Metingen 1, 2 en 3. Report prepared for Ministerie van Verkeer en Waterstaat. Report VWA/121/07/Wi, Deventer, the Netherlands.

Clarke, M., M. Dix and P.B. Goodwin (1982). Some issues of dynamics in forecasting travel behaviour - A discussion paper. Transportation, 11: 153-172.

Daganzo, C. and Y. Sheffi (1982). Multinomial probit with time-series data: unifying state dependence and serial correlation models. Environment and Planning A, 14: 1377-1388.

Golob, J.M., L.J.M. Schreurs and J.G. Smit (1985). The design and policy applications of a panel for studying changes in mobility over time. Presented at International Conference on Travel Behaviour. Noordwijk, the Netherlands, April (forthcoming).

Golob, T.F. and H. Meurs (1985). Biases in response over time in a seven-day travel diary. Transportation (forthcoming).

Golob, T.F., L. van Wissen, and J.M. Golob (1985). A panel-data analysis of the dynamics of transport mode use. In Proceedings of the PTRC Summer Annual Meeting, University of Sussex.

Hensher, D.A. and N. Wrigley (1985). Statistical modelling of discrete choices with panel data. Presented at International Conference on Travel Behaviour. Noordwijk, the Netherlands, April (forthcoming).

Goodman, L.A. (1978). Analyzing Qualitative Categorial Data. London: Addison Wesley.

Goodwin, P.B. and A.D. Layzell (1985). Longitudinal analysis for public transport issues. In G.R.M. Jansen, C.J. Ruygrok and P Nijkamp, eds. Transportation and Mobility in an Era of Transition. Amsterdam: North Holland.

Johnson, L. and D.A. Hensher (1982). Application of multinomial probit to a two-period panel data set. Transportation Research A, 16-457-464.

Koeppel, K.W.P and D.T. Hartgen (1983). Where panels work: some examples from transportation planning. Presented at the World Conference on Transportation Research, Hamburg, April.

McCullagh, P. and J.A. Nelder (1983). Generalized Linear Models. London: Chapman and Hall.

Meurs, H. and M. Klok (1985). Het gebruik van longitudinale paneldata in verkeers- en vervoerstudies (use of longitudindal panel data in traffic and transportation studies). Colloquium Vervoersplanologisch Speurwerk, 's-Gravenhage.

Nelder, J.A. and R.W.M. Wedderburn (1972). Generalised linear models. Journal of the Royal Statistical Society A, 135:370-384.

Smart, H.E. (1984). The Dynamics of change - applications of the panel technique to transportation surveys in Tyne and Wear. Traffic Engineering and Control, 25:595-598.

Wissen, L. van, and E. Zondag (1985). Analyse van veranderingen in gebruik van vervoermiddelen met behulp van panelgegevens (analysis of change in use of modes using panel data). Colloquium Vervoersplanologisch Speurwerk, 's-Gravenhage.