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The Trip Chaining Activity of Sydney Residents: A Cross-Section Assessment by Age Group with a focus on Seniors

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ABSTRACT: In this paper we use a pooled (2002-2004) cross-section of the Sydney travel survey, an annual continuous survey since 1997, to investigate the current profile of trip chaining travel activity of individual's in 5-year groups, with a particular focus on those over 64 years old (i.e., seniors), given the aging of the population. Multiple Correspondence Analysis is used to establish causality of nonlinear and non-monotonic relationships between socioeconomic descriptors and measures of travel behaviour (assessed as trip chains). A benchmark setting for today not only establishes the way in which the elderly currently 'cope' with the existing supply network and the available modal alternatives, given their needs, but also is useful in providing hints as to what might be the key emerging transport policy and planning challenges in the future to serve this growing and increasingly influential population sub-strata. The main policy finding is that after age 64, travel demand shifts from car driving (partly linked to loss of driving license, but partly through choice), to car passenger and then to public transport in complex trip chains, especially for singles and for all women.

KEY WORDS: ***Trip chains, driving license, travel behaviour, aging population***

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1. Introduction

Individuals over the age of 64, referred to as seniors, are increasingly recognized as a population grouping that is likely to have a much greater impact on the transport system in the future than it has today. Most importantly, it is suggested that their travel needs are likely to be both very heterogeneous within the age range but also different from those of individuals in the currently more populous age bands, including commuters. Trip timing, the number of trips and the modes available are likely to be different to the younger populations; yet multi-modal planning in most geographical jurisdictions is heavily based on commuting and others in the younger age groups.

With an aging population in many societies, the transportation needs of the elderly are gaining increasing attention (Alsnih and Hensher 2003). The growing demands for mobility and accessibility of this age group grow in significance relative to the needs of younger, non-retired populations (Smith and Sylvestre 2001, Su and Bell 2006). Recent findings by Paez et al. (2006) support the proposition that trip making propensity decreases with age; however, they also find that this behavior is not spatially homogeneous, and exhibits a large degree of variability – a finding that highlights the challenges of planning transportation for the elderly. The reality is that the transportation needs of the elderly are just as significant as those required of younger, non-retired populations. Add to that the increased need for transportation options for those whose age or physical condition make it impossible for them to take advantage of traditional forms of public transport, and the transportation issues facing the elderly take on even greater significance. Just getting out and about is of immense social, psychological and emotional benefit.

To assist in developing a framework for exploring the future travel needs and demands of the elderly (including a major concern about social exclusion, with the loss of the ability to drive a car), it makes good sense to identify a benchmark setting today, which not only establishes the way in which the elderly currently 'cope' with the existing supply network and the available modal alternatives, given their needs, but also is useful in providing hints as to what might be the big transport policy and planning challenges in the future to serve this growing and increasingly influential population sub-strata.

This paper draws on three years of data on travel activities from the continuous annual Sydney travel survey. Since the late 1990's a rolling survey of 3,000 annual household interviews has been undertaken in the Greater Metropolitan Area of Sydney. The survey uses a travel activity diary to collect travel information over a twenty four hour period, providing information for the average weekday and the average weekend day. Every three year cycle generates sufficient sample size to pool the data and create a single cross-section, equivalent in size to a typical survey undertaken every 10-years in most cities around the world. We have pooled the 2002 to 2004 data of 15,431 individuals. We present findings for the entire population of travellers (including those who made no trips in the survey period), by age group, to gain an understanding of the travel behaviour of younger and older groupings, and to speculate as to whether there are signals on the travel needs and expectations of future senior and elderly cohorts.

We have selected a trip chain perspective to study the travel patterns of each age group, since they represent more realistically the ways that individuals use the multi-modal transport networks than do linked one-way trips. We have configured the data set at the

individual trip chain level with details of the characteristics of an individual and the household they reside in.
This paper is organized as follows. The next section provides an extended descriptive analysis of the data as a way of identifying some of the key differences in travel activity of individuals in each 5-year age grouping. The evidence provides the basis for a Multiple Correspondence Analysis (MCA) in a subsequent section, to establish causality of nonlinear and non-monotonic relationships between socioeconomic descriptors and measures of travel behaviour (assessed as trip chains). The final section draws out some policy and planning implications of our findings and its links to the broader literature, setting an agenda for ongoing research on the travel needs of an aging population.

2. Descriptive Analyses

2.1 The Trip Chain Setting

A trip chaining perspective has been chosen to represent travel activity. Formally, a trip chain is a sequence of trips that begin from a location (home in these analyses) and return to that location after none, one, or more intermediate stops of any duration. Trip chain types and definitions are shown in Appendix Table A1, adapted from Hensher and Reyes (2000). Trip chain analysis, giving 24,423 observations in the Sydney sample, reflects the door-to-door outward and return trip, presenting a relatively more holistic, rather than partial, assessment of individual travel behaviour than the more common uni-directional linked trip approach.

Such chains are either work or non-work centric. Work trip chains include at least one work or work-related trip and non-work trip chains include all other trips. The work trip chain definitions were more numerous because these may involve one or more non-work trips. For example, people may drop off their children and stop for petrol on their way into work, go to the bank during their lunch break, pick up the children and then drop them off for soccer practice before finally reaching home. Trip chains were constructed to separate car passenger trip chains from car driver trip chains. This is an important distinction when looking at the travel patterns of the aged. Thus, eighteen trip chains in total were constructed, some *simple* (e.g., home to work to home bys car as driver) and others more *complex* (e.g., home to work to non-work and home by car as driver). See Alsnih and Hensher (2005) for further details.

The literature suggests that trip chaining behaviour might be expected to increase in general as a population ages, due in part to the higher proportion of the population in the future being over 65 years old (and especially over 75 years old), who are less constrained than when undertaking single-purpose commuting activity. The literature recognises the growth in more active lifestyles of seniors (‘fitting all needs into the limited time and space’) and the ability, through trip chaining, of satisfying multiple objectives in one outing (Banister and Bowling, 2004; Metz, 2003; ECMT, 2002; Rees and Lyth, 2004). In semi-retirement and full retirement, an increasing number of women may want to maintain their active lives, further reinforcing the relative attractiveness of the car and the unattractiveness of public transport (Donaghy *et al.*, 2004; Price, 2003; Alsnih and Hensher, 2003; Bonham *et al.*, 2004).

2.2 Purpose and Complexity of Trip Chaining by Age Group

Any investigation of the travel patterns of a population tends to begin by focusing on the relationship between age and purpose of travel that involves the work activity (Figure 1). We will not diverge from this perspective, since an assessment of the travel patterns of the elderly (defined herein as individuals over 64 years old) is best portrayed relative to the travel behaviour of the non-elderly. In this way we can establish agendas that speak more specifically to the contemporary differences in actual travel demands of the two age groups, and hence better inform policy and planning as the mix of the population shifts, age-wise.

Age can be considered to be a continuous variable at first approximation. It is scaled at equal intervals of 5 years until the top category. The sample mean of persons 85 and older is 88.3 and the median is 87, so the interval between the highest two categories is also approximately 5 years.

The generation of work trip chains begins declining at age 50 (Figure 1), but the decline is at a decreasing rate from age 60-64 to 80-84. The generation of non-work trip chains decreases linearly with age from 65-69 through 80-85, at which point the rate of decrease is more dramatic. With regard to the complexity of home-based trip chains, simple chains – those involving only a single away-from-home destination – decrease, from a peak at age 40-44, at a faster rate than do complex chains. Age 50-54 is the point at which travel complexity begins becoming an increasing function of age, at an increasing rate. It is also the age category at which work orientation begins becoming a decreasing function of age, at a decreasing rate. The growth in complex chains in the elderly age groups sends a warning signal to the role that inflexible and/or poorly networked public transport might play in servicing the elderly.

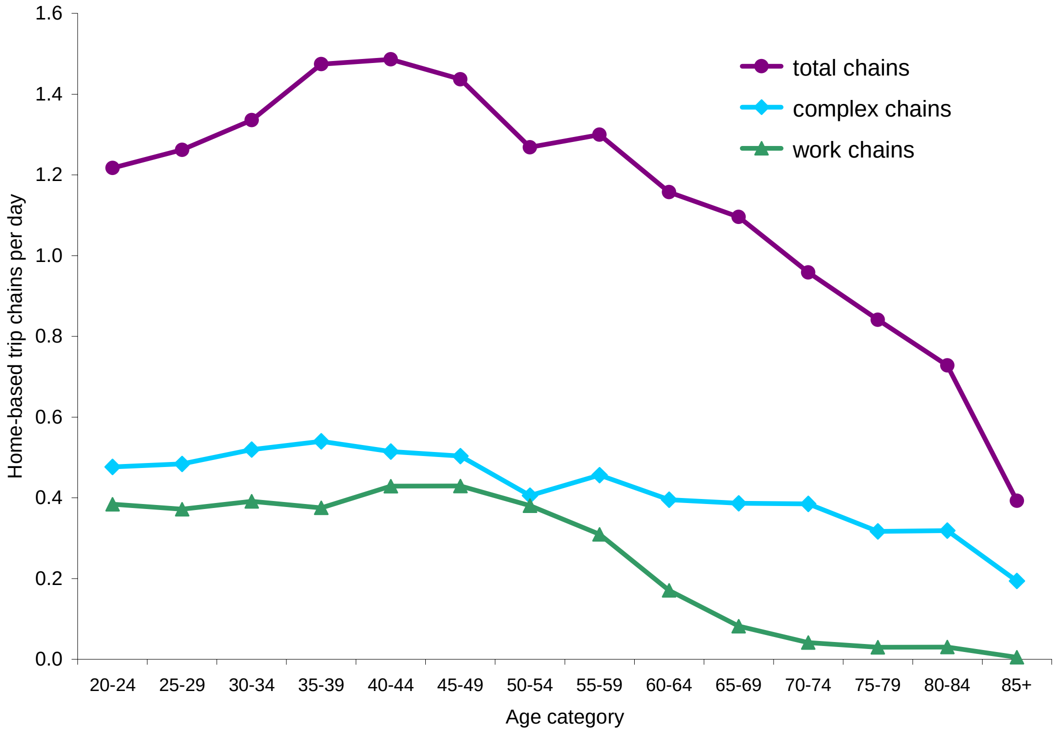

Figure 1: Average home-based trip chains per day by age, purpose, and complexity

2.3 Mode Usage by Age

Greater car dependency amongst older persons is evident in all Western societies (Gantz, 2002; Rosenbloom, 2001; Donaghy *et al.,* 2004; Tacken, 1998). In addition, older drivers are the fastest growing segment of the driving population, in terms of license rates and distances travelled (Okola and Walton, 2003; Rosenbloom, 2003; Banister and Bowling, 2004). Young seniors[1], those aged 65 to 74 years, are travelling longer distances, are making more trips and the purposes of these trips are now more varied (Banister and Bowling, 2004; Rosenbloom, 2001; Rosenbloom and Morris, 1998; Burkhardt *et al.*, 1998; Hu and Young, 1999; Tacken, 1998). Commuter trips, once made by public transport, are now non-work trips made by the automobile (Rosenbloom, 2001). The major relationship between age and mode usage is the rate of car driver trip chains, which peaks in the 40-44 age category (Figure 2).

The rapid decline in car driver trip chains as individuals age beyond the 40-44 age group results in a substantial increase in the proportion on non-car driving trip chains. For most elderly travellers, driving however is still popular; 36.4% of persons aged 85 and older drive, while 45.5% travel as car passengers, and 18.2% travel by public transport. Both car passenger and public transport mode split increase with age at an increasing rate (but a small absolute increase as per Figure 2) from their minimums at age 40-44. These results are almost identical for weekdays versus the entire week.

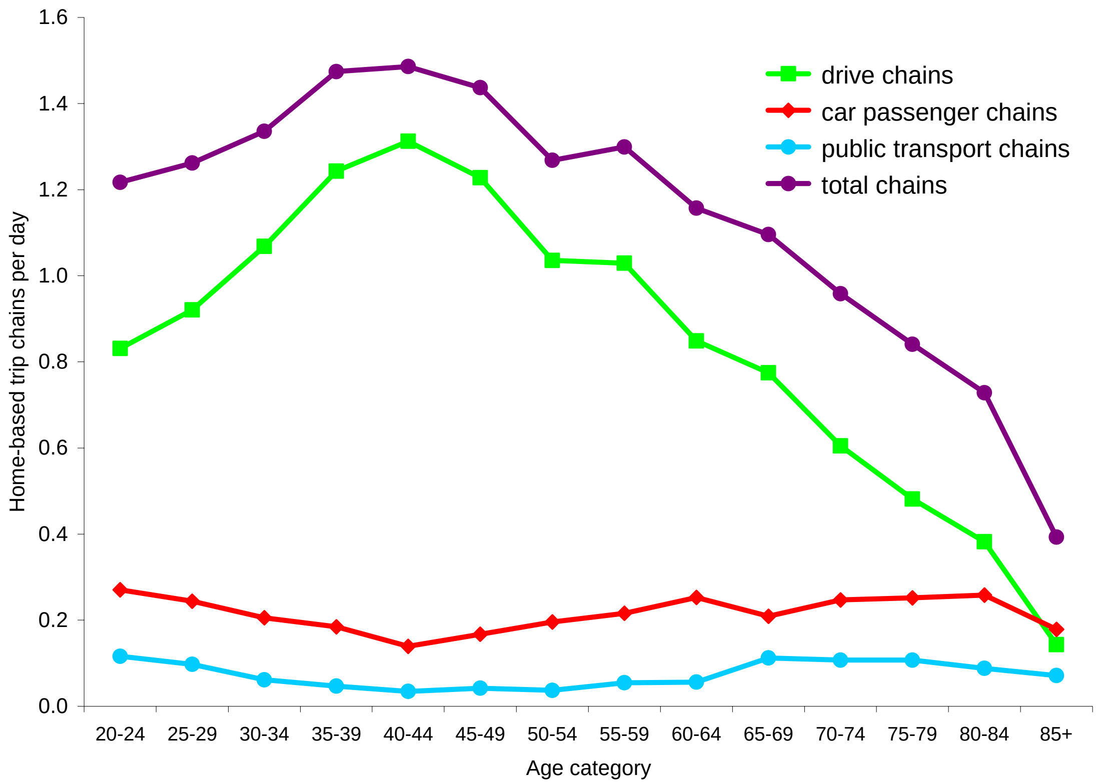

Figure 2: Average home-based trip chains per day by age and mode

[1] Old seniors are those aged 75 years to 84 years, whilst those aged 85 years and over are referred to as the elderly (Alsnih and Hensher, 2003).

These relationships raise the question of how driving license holding is related to age and the role that the ability to drive a car has on the switch to car as a passenger or to public transport. As shown in Figure 3, license holding for women begins falling off at about age 50, whilst license holding for men falls off dramatically beyond age 79. Currently, of the individuals over 84 who have to undertake a mandatory driving examination in New South Wales if they wish to renew their licence, over 65 percent of females and 71 percent of males passed this examination in 2004 (Table 1)[2]. It is not known how these pass rates will change in the future, as more people enter this stage in their lives, although we might expect a higher absolute number retaining their driving license. However, currently people aged 85 years and over with a driver's license only represented 16 percent of the total population in this age group (RTA, 2004).

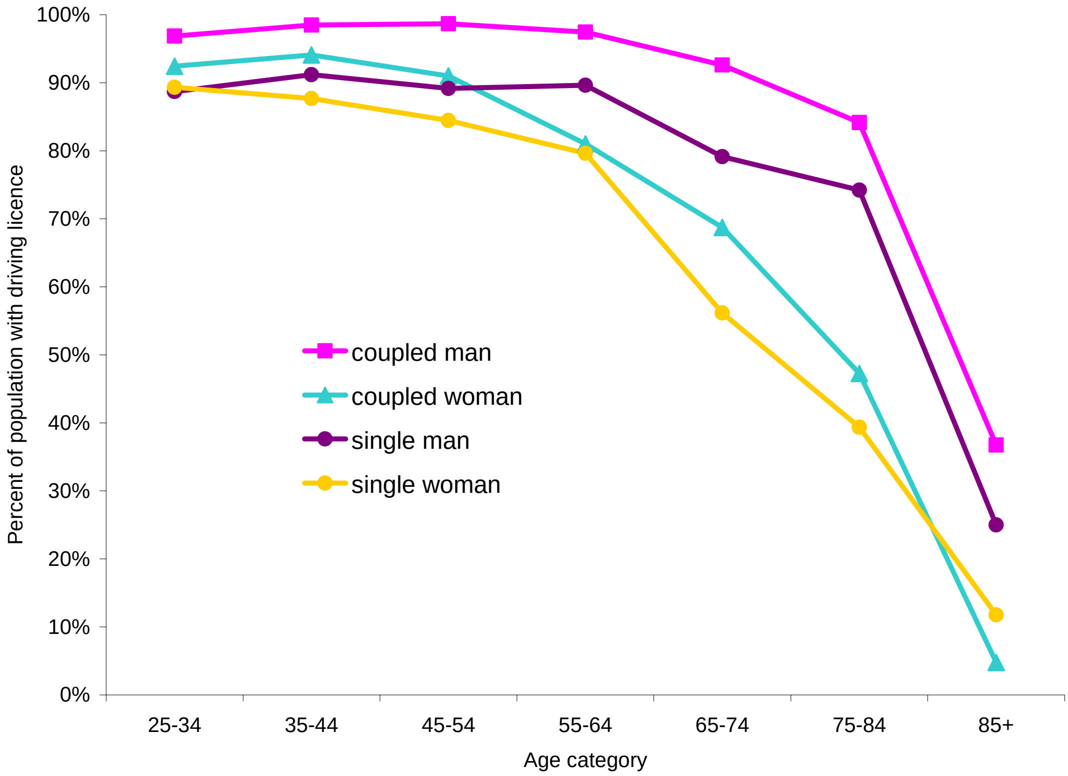

Figure 3: License holding by age, gender and living circumstance

[2] The high incidence of failure for individuals under 85 years old is of interest as well, with the majority being individuals who have moved to Australia and/or who have had a license previously cancelled.

Table 1: Profile of Driving License Test results by Age and Gender (Source unpublished RTA data files)

			Percent Fail	Percent Pass	Total
Female	Age Groups	55-59	70.30	29.70	596
		60-64	67.80	32.20	205
		65-69	70.99	29.01	131
		70-74	74.12	25.88	85
		75-79	72.31	27.69	65
		80-84	68.89	31.11	135
		85-89	*34.97*	*65.03*	*6520*
		90 +	*29.80*	*70.20*	*933*
	Total		**39.35**	**60.65**	**8670**
Male	Age Groups	55-59	52.29	47.71	765
		60-64	60.35	39.65	396
		65-69	69.39	30.61	245
		70-74	67.57	32.43	185
		75-79	65.95	34.05	185
		80-84	62.62	37.38	321
		85-89	*29.67*	*70.33*	*12668*
		90 +	*28.38*	*71.62*	*2488*
	Total		**33.17**	**66.83**	**17253**

Note: Compulsory annual test after 84 years old

However, the real interest in the future is the expected increase in the population aged over 84 years and their modal preferences and activity. This growing sub-population is increasingly remaining healthy, and so one might expect their absolute license-holding to increase over time. One question to be addressed is what will happen in the future if the license-holding curves (Fig 3) shift to the right. Obviously driving is closely related. Given recent evidence (Catchpole *et al.* 2005, Burns 1999, Skinner and Stearns 1999) that drivers over 75 years old have specific problems in driving that are very different to younger drivers, such as the ability to avoid collisions with parked vehicles, buildings and fences, as well as judgment of distance or vehicle control, and an ability to turn fully into lanes (suggesting compulsory fitting of distance sensors and power steering), the prioritization of road environmental policy is likely to change markedly (Davey 2004).

Since the life expectancy of women is greater than that of men, all of the gender effects are likely to be related to whether or not an elderly person is living alone, or with spouse or partner. From age 60, the proportion of women living on their own increases rapidly with age; the same is not true for men. At age 85 and above, two-thirds of men are still living with their partner or spouse, compared to only seventeen percent of women. This has implications for mobility since many of the women in their 80's have never held a driver's license (compared to those who will be in their 80's in the future), and the loss of the male partner has immediate impacts on the modal options. Family and friend networks and support groups can provide some of the 'lost' mobility but it is often the case that actual travel activity declines substantially.

The basic differences between men and women in terms of license holding is not changed by taking into account whether or not an individual is living with a spouse or partner (Figure 3). Single men and women are less likely to be drivers across almost all age groups.

Consequently, the driving status of coupled men and single women are generally the most dissimilar. For example, in the 65-74 age group, 93% of men with partners are drivers, while only 56% of single females are drivers. For the 75-84 age group, license holding is 84% for partnered men, compared to 39% for single women.

2.4 Mode Usage by Age and Living Circumstance

2.4.1 Car Driving Travel

Mobility by car driver as a function of age and whether a person is living with a spouse or partner (generally those who are married) basically reflects the license holding patterns of Figure 8. Men with a spouse or partner are most likely to make a driving home-based trip chain, but the incidence of such chains falls off rapidly for all segments as a function of age. Nonetheless, driving remains the predominant mode for men of all age groups, particularly for married men. Even for those aged 85 or older, 60.7% of all chains are by driving for men with spouse or partner. In contrast, less than 20% of women aged 85 or older, whether partnered or not, make their trip chains by driving. The difference between women with and without partners is greatest in the 75-84 age group, where their male partners are still more likely to be drivers.

2.4.2 Car Passenger Travel

Car passenger home-based trip chains peak in the 75-84 age group for all segments except men with spouses or partners (Figure 4). This fall-off in car passenger chains in the oldest age group is due to the fall-off in total mobility. With the exception single men, car passenger mode split is a monotonically increasing function of age for all segments from age 45. For single men, the biggest jump in car passenger mode split occurs between the 65-74 and 75-84 age groups.

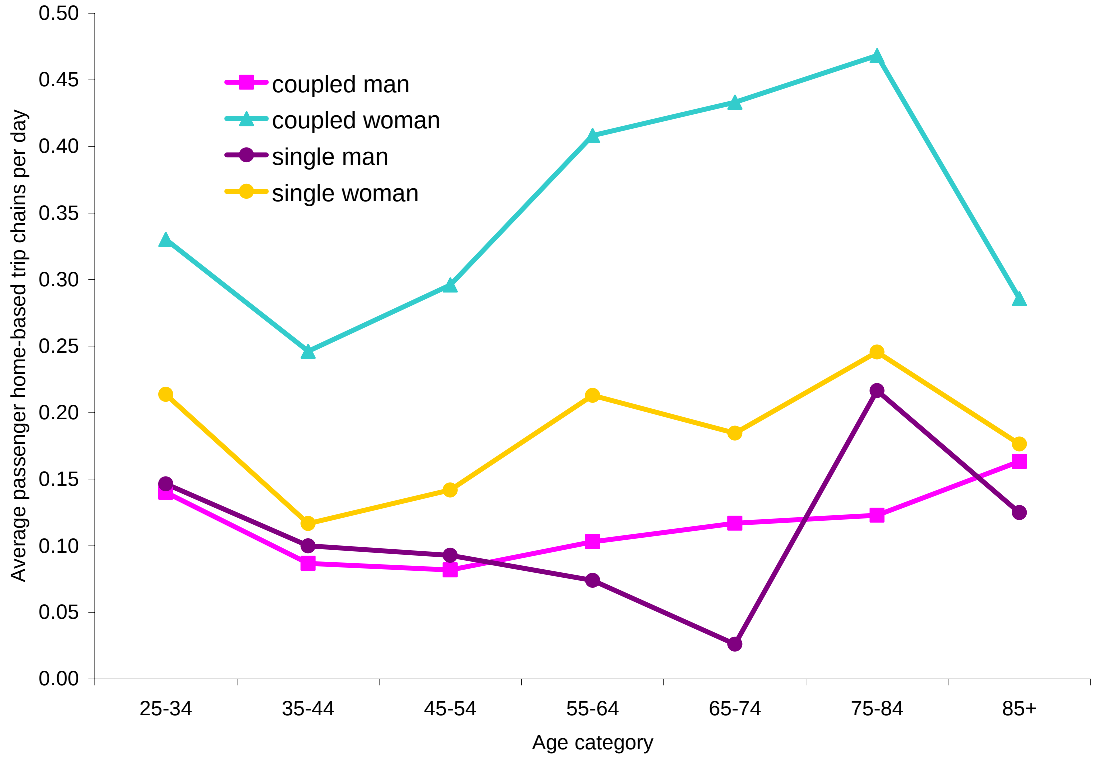

Figure 4: Average number of car passenger home-based trip chains per day by age, gender and living circumstance

2.4.3 Public Transport Travel

A particularly interesting feature of the comparisons across age groups is the role that public transport currently plays as one moves into the elderly age range. There are views that the elderly rely more on public transport than those in younger age groups; the evidence bears this out in absolute and percentage terms. However, with growing numbers of the elderly in the future maintaining their health and hence availing themselves more of car driving, it is expected that the absolute and percentage of elderly using public transport might decline. How much it declines will depend on both stick and carrot policies.

In 2002 however the evidence suggests that single men and women of all age groups are much more likely to use public transport, as compared to their coupled counterparts (Figure 5). In terms of the absolute number of home-based trip chains using public transport, for those living without spouses or partners, demand peaks in the 65-74 age group. Public transport mode split is an approximately increasing function of age for all gender and living circumstance segments.

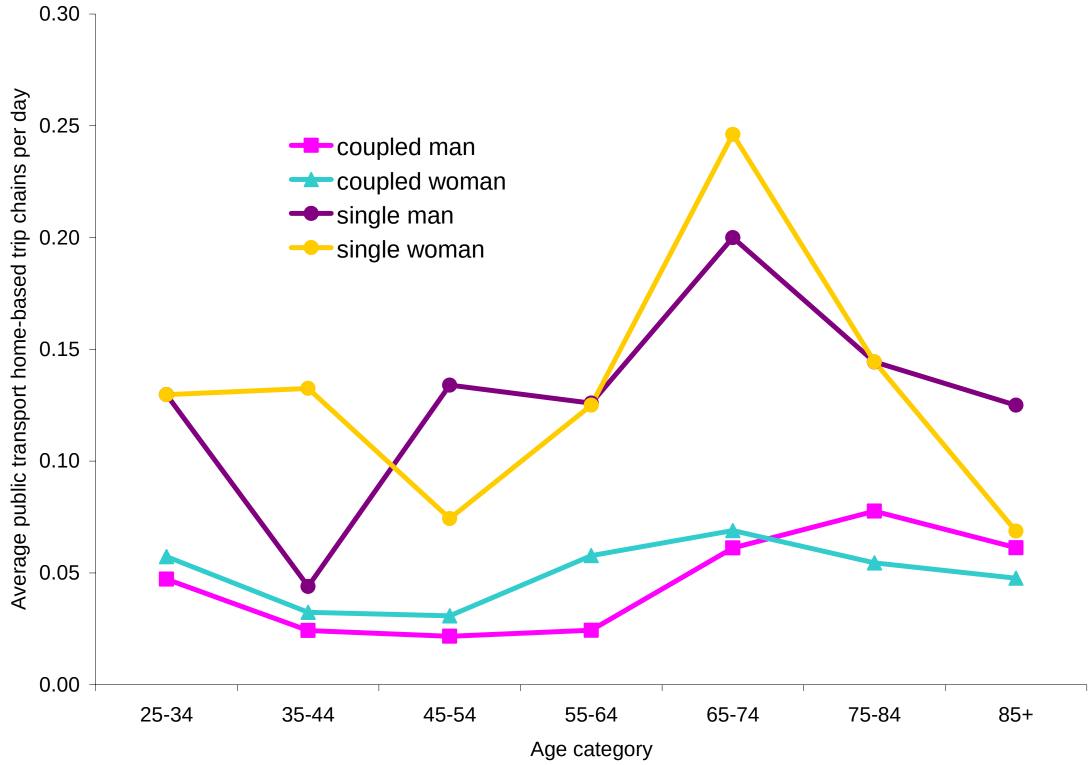

Figure 5: Average number of public transport home-based trip chains per day by age, gender and living circumstance

2.5 Implications for Modelling Travel Behaviour

These descriptive analyses reveal that the combination of gender and living circumstances, that is, whether adults are living together with a partner or alone, is important in modelling the relationship between age and travel behaviour. It is also readily apparent that age should be treated as a categorical variable. We have seen that the relationships between age and various aspects of travel demand are not only nonlinear, but in many instances non-monotonic. The same is likely to be true of other sociodemographic variables, such as income. Consequently, our models must be able to accommodate multiple multi-category variables, and one applicable method is presented in the remainder of this paper.

3. A Model of Travel Behaviour, Age, Income, and Living Circumstance

Our descriptive analysis clearly shows that the multi-category variables such as age group have nonlinear and even non-monotonic relationships with categorical measures of travel behaviour such as trip chain generation, whether a mode is used at all, and car ownership. A highly effective way of modelling the nonlinear relationships between multiple categorical variables is Multiple Correspondence Analysis (MCA).

Multiple Correspondence Analysis is a method that captures the fundamental relationships among categorical variables in much the same way that Factor Analysis (specifically, Principal Components Analysis - PCA) captures the fundamental relationships among linear continuous variables. Correspondence Analysis was developed and refined by Jean-Paul Benzérci and his colleagues in the 1960's and 1970's (Benzérci, 1973). Until recently, its use in English-speaking countries has been impeded by the language barrier and cultural differences in presentation. However, use of all forms of Correspondence Analysis is accelerating in many fields, with the general exception of econometrics (Greenacre, 1984). Methods similar to Correspondence Analysis have been developed independently in many countries (e.g., Homogeneity Analysis of Gifi, 1990). Multiple Correspondence Analysis (Analyse des données multidimensionnelles) extends Correspondence Analysis to more than two variables (more than one contingency table) (Greenacre, 1994).

MCA uses Chi-square, as opposed to Euclidean distance in PCA, as a measure of similarity. MCA is a nonparametric method in which no assumptions are made concerning an underlying distribution of the data. This distinguishes the method from log linear modelling, which is also applied to data described in terms of multiple contingency tables.

3.1 Model Specification

Our model contains seven categorical variables, three socio-demographic variables and four travel related variables, as described in Table 2. The total sample size is 15,431. The distributions are sufficient in all variable categories to avoid any outliers problem, which manifests itself in terms of small expected frequencies in any cell of a two-way contingency table.

Table 2: Variables in the Multiple Correspondence Analysis Model.

Variable and category	N	%	Variable and category	N	%
Age			Public transport usage		
15-24	2,456	15.9%	no transit trips	14,429	93.5%
25-34	2,612	16.9%	transit trips	1,002	6.5%
35-44	3,154	20.4%	Car driving usage		
45-54	2,721	17.6%	no drive trips	6,863	44.5%
55-64	1,994	12.9%	driving trips	8,568	55.5%
65-74	1,395	9.0%	Car passenger usage		
75-84	903	5.9%	no passenger trips	12,749	82.6%
85+	196	1.3%	passenger trips	2,682	17.4%
Gender/ living circumstance			Total home-based chains		
coupled man	4,883	31.6%	no trips	3,279	21.2%
coupled woman	5,180	33.6%	1 chain	7,062	45.8%
single man	2,436	15.8%	2 chains	3,495	22.6%
single woman	2,932	19.0%	3+ chains	1,595	10.3%
Household income			Car ownership		
<$28k	3,798	24.6%	no car in household	1,034	6.7%
$28k-$45k	2,015	13.1%	car in household	14,397	93.3%
$45k-$60k	1,936	12.5%			
>$60k	7,682	49.8%			

3.2 Variance Accounted For and Discrimination

We show results for only the first two MCA dimensions, so that all our representations of optimal variable relationships can be graphed in two-dimensional space. Extending the model to more than two dimensions requires depiction in three-dimensional or higher spaces, leading to multiple two-dimensional plots of various combinations of axes, which can be highly complicated. The extraction of further dimensions does not affect the first two dimensions, as all dimensions are mutually independent (orthogonal).

The variance accounted for by the first two dimensions of the MCA solution are listed in Table 3. Results for a third dimension are also shown for comparison purposes. The two dimensions together account for 51% of the variance in the eight categorical variables, with the first dimension being about 1.5 times more effective than the second dimension. Thus, reducing the data from eight categorical variables to two continuous orthogonal variables, a four to one reduction in complexity, results in only a two to one reduction in information. Cronbach's alpha, a coefficient that measures how well a set of variables is measured by a one-dimensional latent construct, can be used to compare the performances of the dimensions. Using this metric, the first dimension is about 1.5 times as effective as the second dimension, which is in turn about 1.4 times as effective as the third dimension. Since all dimensions are orthogonal, this shows that we can disregard the third and subsequent dimensions with no adverse effects on our conclusions, except a potential loss of the most subtle (tertiary) relationships.

Table 3: Inertia Results of the Multiple Correspondence Analysis Model.

Dimension	Variance accounted for		Cronbach's Alpha
	Total (Eigenvalue)	% of variance	
1	2.421	30.3%	0.671
2	1.663	20.8%	0.455
Total with 2	4.084	51.0%	
3	1.384	17.3%	0.316

The MCA transforms the categorical variables to a Euclidean system in which calculations of ordinary product-moment correlations and other linear statistical measurements are possible. The centroid coordinates of all of the variable categories are listed in Table 4. It is most efficient to interpret these results by plotting the category coordinates in the two-dimensional space of the latent dimensions, and that is the subject of the remainder of this paper.

Table 4: Category Coordinates for the Multiple Correspondence Analysis Solution.

Socio-economic Variable and category	Dimension 1	2	Travel and Mobility Variable and category	Dimension 1	2
Age			Public transport usage		
15-24	-0.58	-1.63	no transit trips	0.10	0.06
25-34	0.23	-0.27	transit trips	-1.49	-0.83
35-44	0.59	0.20	Car driving usage		
45-54	0.47	0.20	no drive trips	-0.88	-0.10
55-64	0.14	0.44	driving trips	0.71	0.08
65-74	-0.69	1.01	Car passenger usage		
75-84	-1.34	1.10	no passenger trips	0.11	0.19
85+	-2.32	1.37	passenger trips	-0.55	-0.92
Gender/living circumstance			Total home-based chains		
coupled man	0.47	0.56	no trips	-0.94	0.79
coupled woman	0.18	0.21	1 chain	0.05	-0.37
single man	-0.32	-1.14	2 chains	0.42	-0.15
single woman	-0.83	-0.37	3+ chains	0.79	0.33
Household income			Car ownership		
<$28k	-0.93	0.76	no car in household	-2.29	0.52
$28k-$45k	0.11	-0.19	Car in household	0.16	-0.04
$45k-$60k	0.25	-0.08			
>$60k	0.37	-0.30			

Discrimination measures of the variance of the distribution for the category weights of each variable on each dimension are listed in Table 5. Interpretation of these results is also pursued in the following sections. We present two-dimensional plots of category scores for subsets of variables as an aid in interpretation. As is customary, the first dimension in all plots is the x or horizontal axis, while the second dimension is the y or vertical axis.

Table 5: Discrimination Measures of the Multiple Correspondence Analysis Model.

Variable	Dimension 1	2	Mean
Age	0.392	0.663	0.528
Gender and living situation	0.228	0.345	0.287
Household income	0.292	0.192	0.242
Public transport usage	0.154	0.048	0.101
Car driving usage	0.627	0.008	0.317
Car passenger usage	0.063	0.177	0.120
Total home-based trip chains	0.291	0.210	0.250
Car ownership	0.375	0.020	0.197
Total	2.421	1.663	2.042
% of variance	30.3%	20.8%	25.5%

3.3 Coordinates: The Three Socio-demographic Variables

The optimal transformation of the three socio-demographic variables, shown in Figure 6, is quite revealing. All three variables are well discriminated by the MCA dimensions. To assist in understanding the richness of the information in the MCA diagrams we will use Figure 6 to interpret the two MCA axes:

> *Dimension one (the x-axis)* represents (+) middle age, partner coupling, and the highest three quartiles of income, versus (-) either young or older ages, single status (especially single status of women), and the lowest income quartile. The steady progression is from single woman to single man to coupled woman to coupled man. On Dimension 1, the 15-24 age group is similar to the 65-74 age group, and the 25-34 age group is similar to the 55-64 age group. The big distinction is between the oldest age group (85 or older) and the 35-54 age groups.
>
> *Dimension two (the y-axis)* represents, in terms of age, a monotonic progression from (-) young to (+) old, with first a rapid transition to middle age, a slower progression among middle-aged groups, an acceleration to the usual retirement age, with only a little progression beyond that threshold. In terms of income, the lowest quartile is distinguished from all else, as in the case of dimension 1, but with an opposite sign. Finally, dimension two distinguishes couples from singles, as does dimension 1, but the main distinction is between single men and coupled men.

The correlations among the optimally scaled socio-demographic variables are 0.304 for age and gender/living circumstance, 0.351 for age and income, and 0.131 for gender/living circumstance. This quantifies the relative orientations of the alignments of the three variables that can be seen in Figure 6.

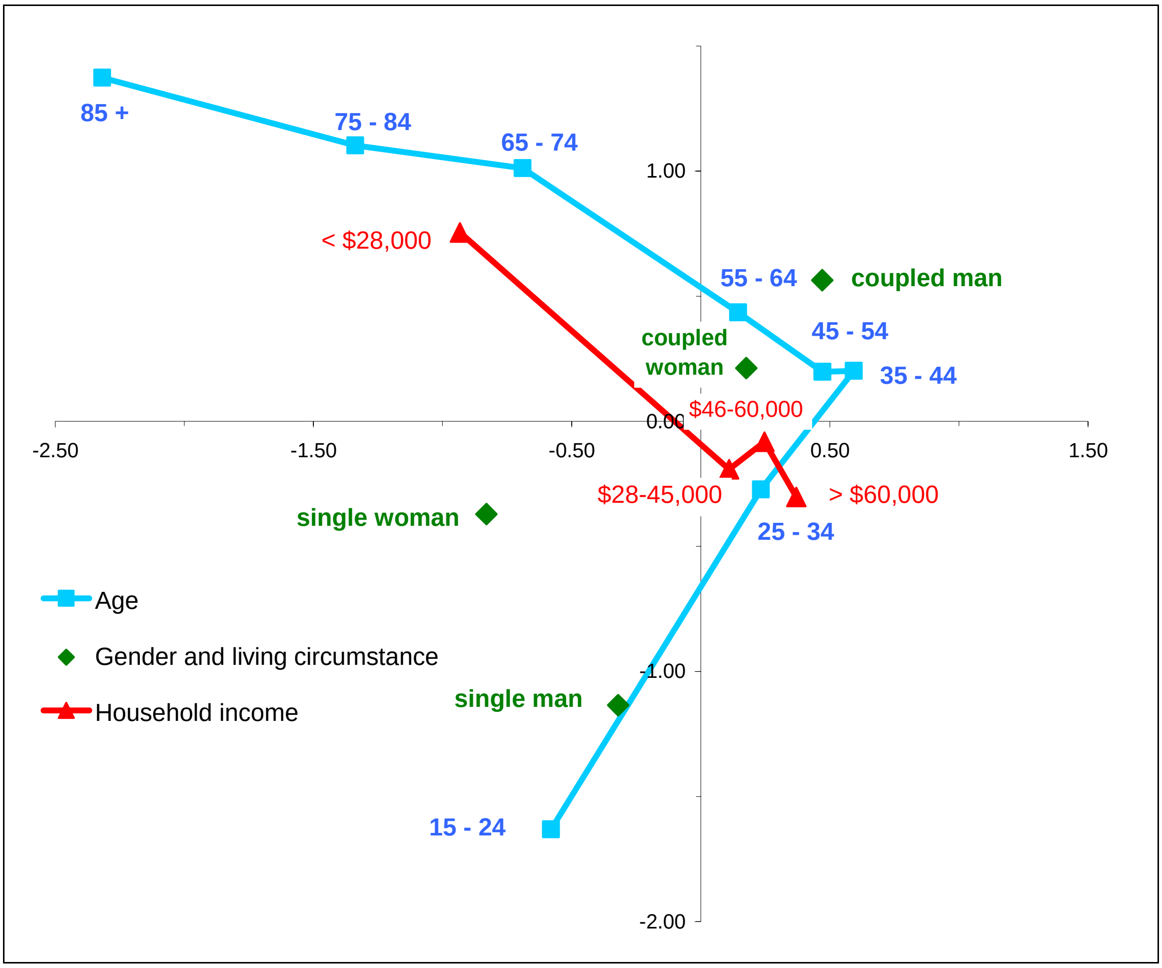

Figure 6: Centroid Coordinates for the Categories of the Three Socio-demographic Variables

3.4 Demand for Specific Modes

The category coordinates for public transport usage are superimposed in Figure 7 on those of the socio-demographic variables. We can see that a *reduction in* public transport demand is consistent with the transition from young to broadly-defined middle age, from single to coupled status, and from the lowest income quartile to any other income quartile. *Increase in* public transport demand is consistent with aging beyond middle age.

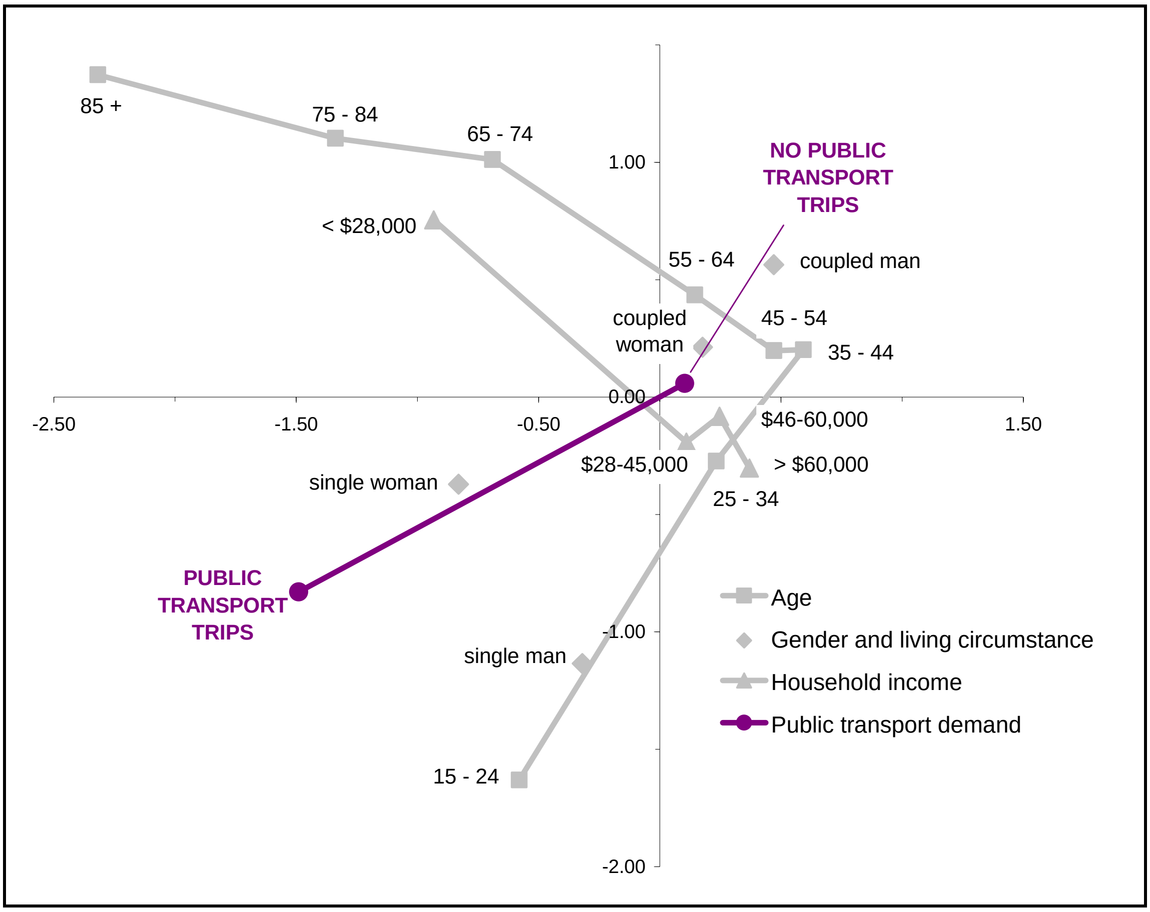

Figure 7: Centroid Category Coordinates for Public Transport Demand and the Three Socio-demographic Variables

The category coordinates for car driving usage are superimposed in Figure 8 on those of the socio-demographic variables. Car driving demand peaks at middle age, and there is very little difference between demand at ages 35-44 and 45-55, with some drop off in demand at ages 25-34 and 55-64. The major reduction in demand is beyond age 64. The model also shows that, in terms of gender and living circumstances, single women and coupled men are at the opposite extremes of driving demand. Finally, low income is also associated with low driving demand.

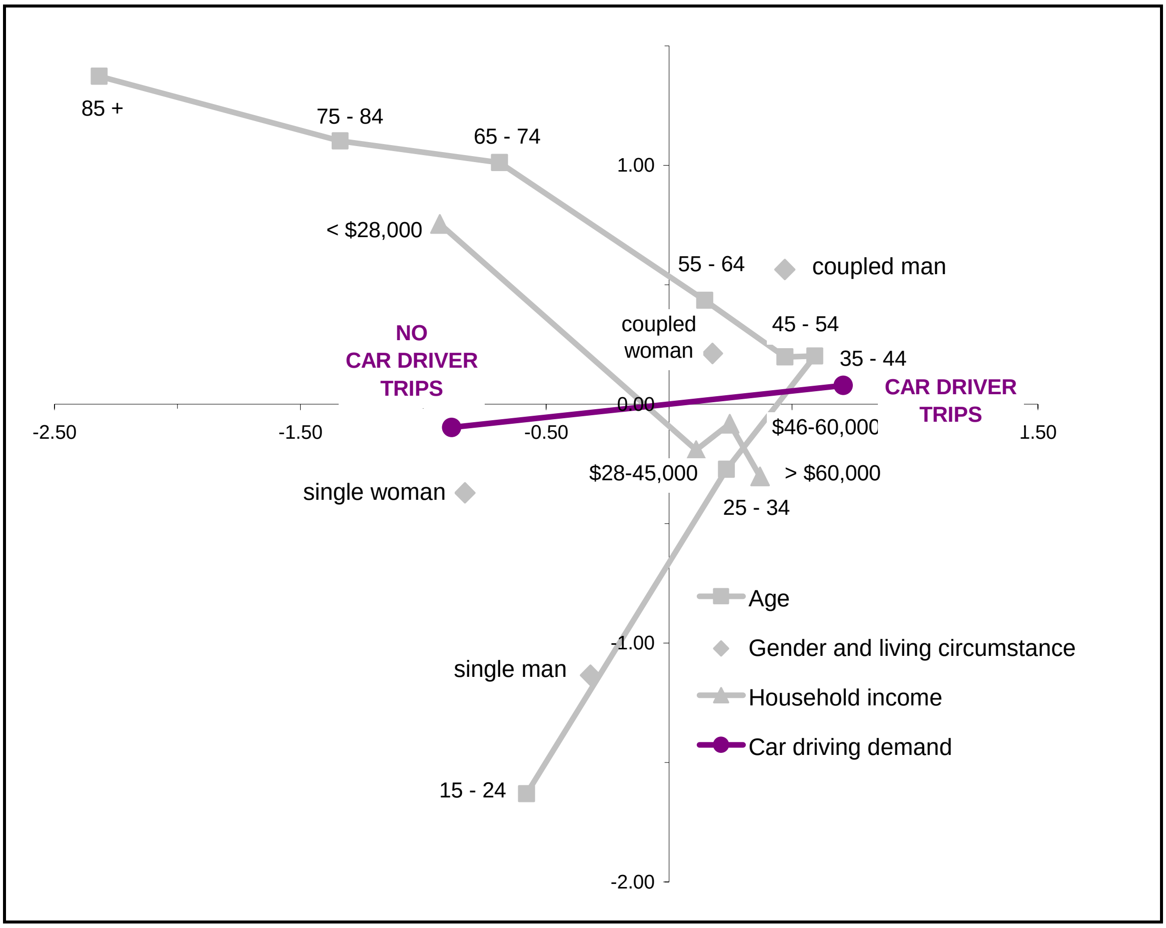

Figure 8: Centroid Category Coordinates for Car Driving Demand and the Three Socio-demographic Variables

A similar plot is shown in Figure 9 for car passenger demand. Here, the second dimension comes into play. Younger and older persons are more likely to make trips as car passengers, singles are more likely than couples, and women are more likely than men. In summary, progression up the younger age regime is directly aligned with a shift in mode from car passenger and public transport to car driving. It is also related to one aspect of total mobility. The older age regime is aligned with car ownership and driving, and a second aspect of total mobility.

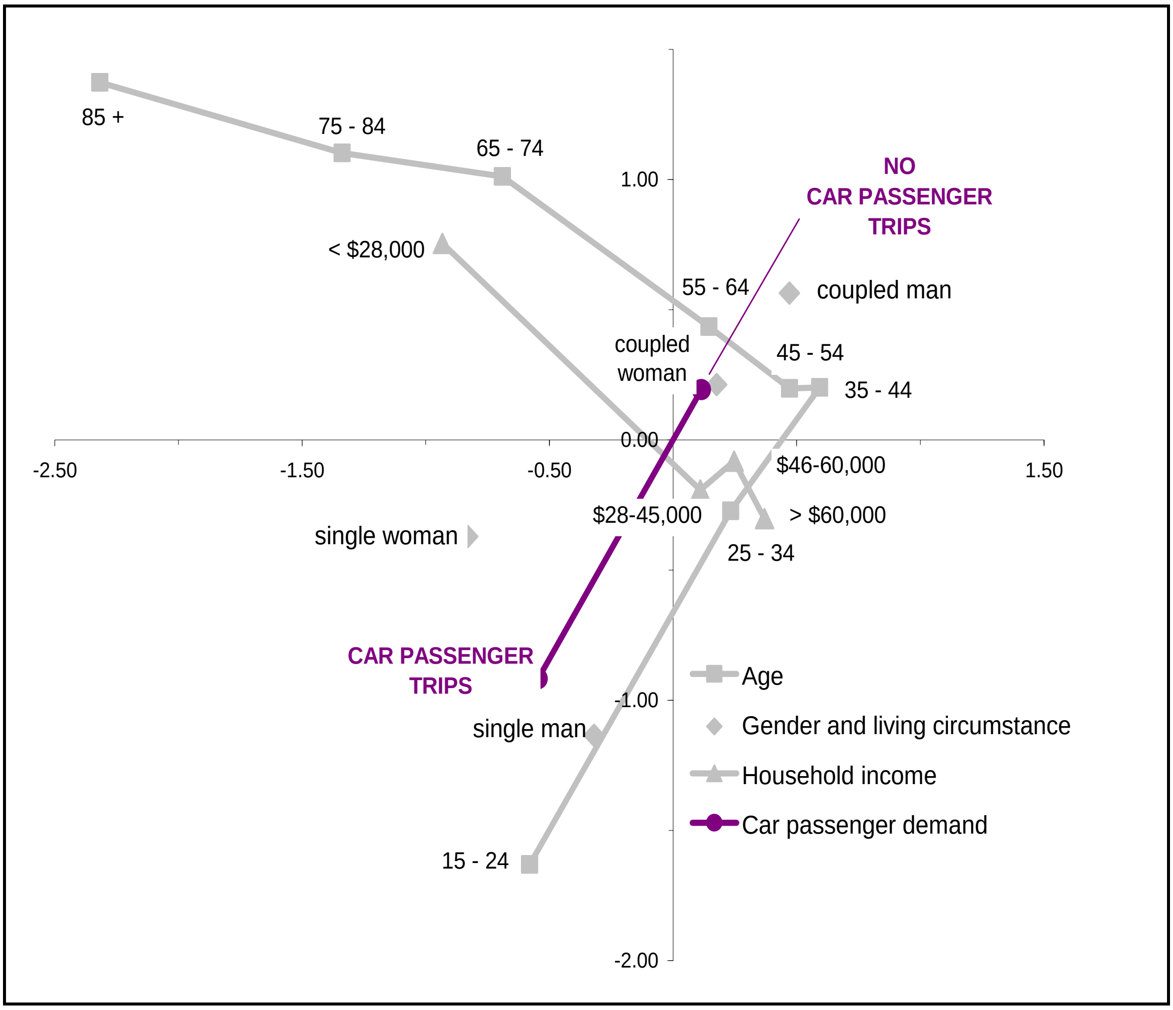

Figure 9: Centroid Category Coordinates for Car Passenger Demand and the Three Socio-demographic Variables

3.5 Trip Chain generation

The category scores for the total number of home-based tip chains are plotted in Figure 10. Here, as in the case of age, the model solution has defined two separate and approximately orthogonal regimes. The distinction between no travel and one home-based trip chain per day is aligned in a NW-SE compass direction, parallel to the upper age regime. Reduced travel activity is more likely among the highest age groups and the lowest income group. The transition from one to two and three trip chains is aligned in the SW-NE direction, toward the apex of the age function. Clearly, the generation of multiple trip chains is maximum among persons in the middle age groups. The model predicts that the difference among numbers of trip chains, for travel active persons, is independent of household income. Couples are likely to generate more chains than singles, and among couples, men are likely to generate more chains than females.

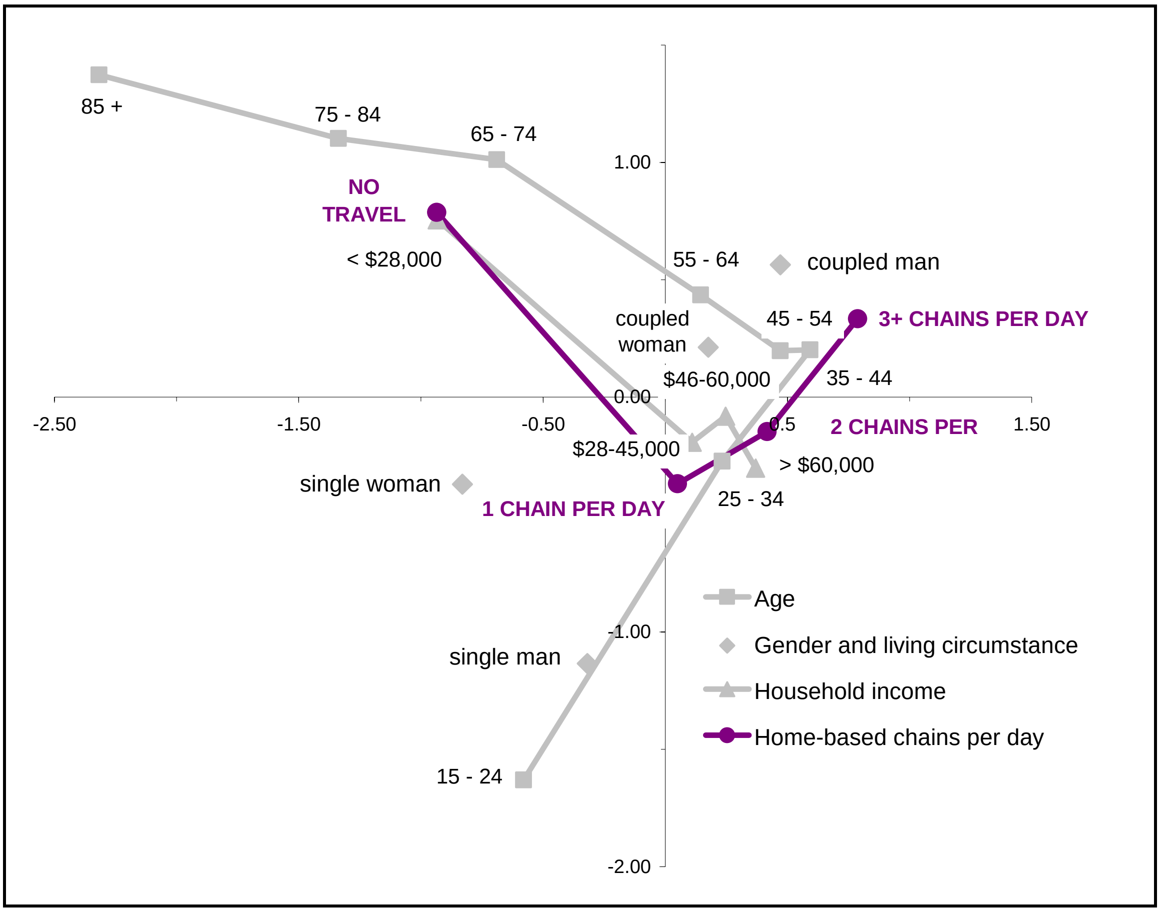

Figure 10: Centroid Category Coordinates for Trip Chain Generation and the Three Socio-demographic Variables

3.6 Car ownership

Scores for the two categories of household car ownership are plotted in Figure 11. Persons in the oldest age groups, the lowest income group, and single women are least likely to reside in households with a car.

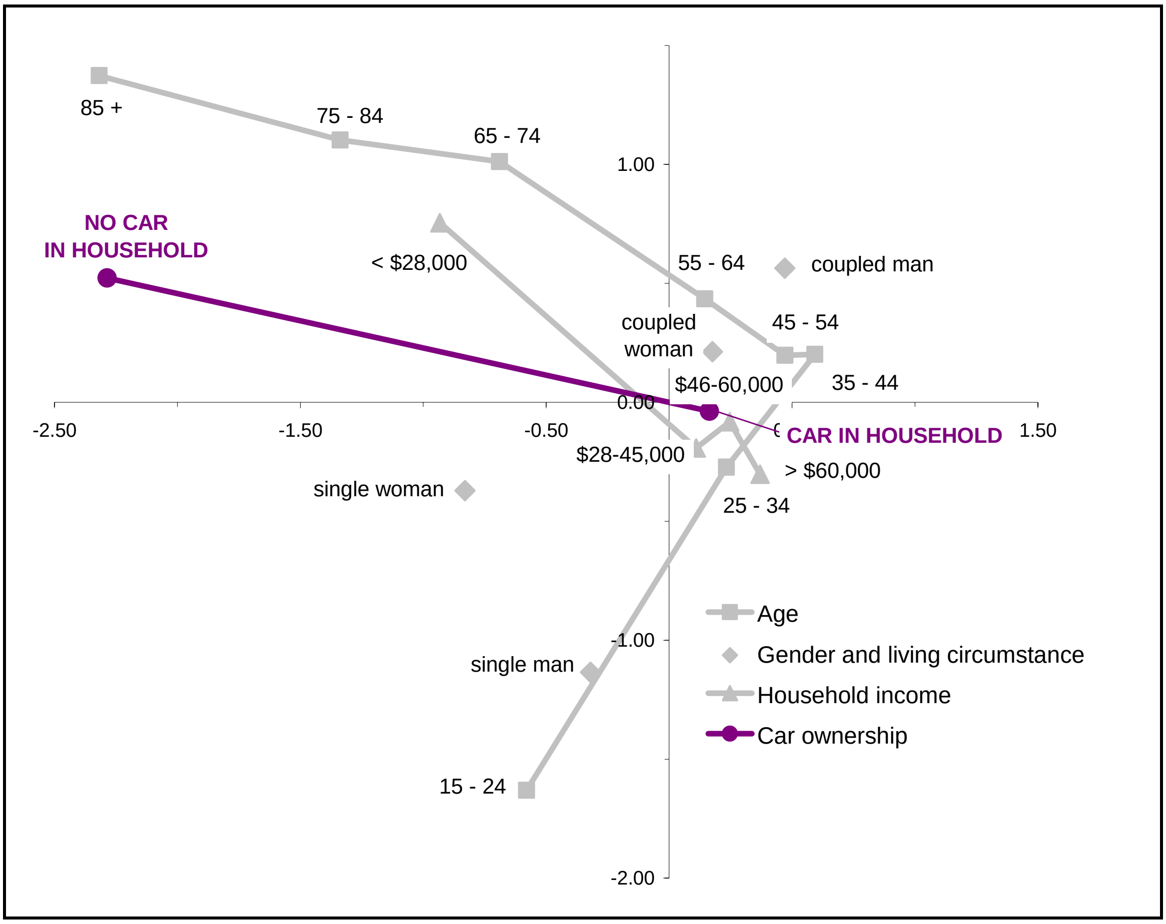

Figure 11: Centroid Category Coordinates for Car Ownership and the Three Socio-demographic Variables

3.7 Relationships between Age and Mobility

All five of the travel and mobility variables are plotted together with age in Figure 12. Our model predicts that, in young adulthood, a person moves in the direction toward car driving away from public transport and car passenger travel, while simultaneously moving from single to couple status (not shown). The effects of gender (also not shown) mean that this process is more dramatic for men, and an income effect causes the transition to be at lower levels of mobility and car ownership for those in the lowest quartile of income. This transition continues, at a reduced pace, from 25 through 44 years, during which time trip generation increases as well. There are then very few changes until age 55. Beginning at age 55, and especially after age 64, the incidence of travel activity decreases with age, and travel demand shifts from car driving to public transport and car passenger, especially for singles and for all women.

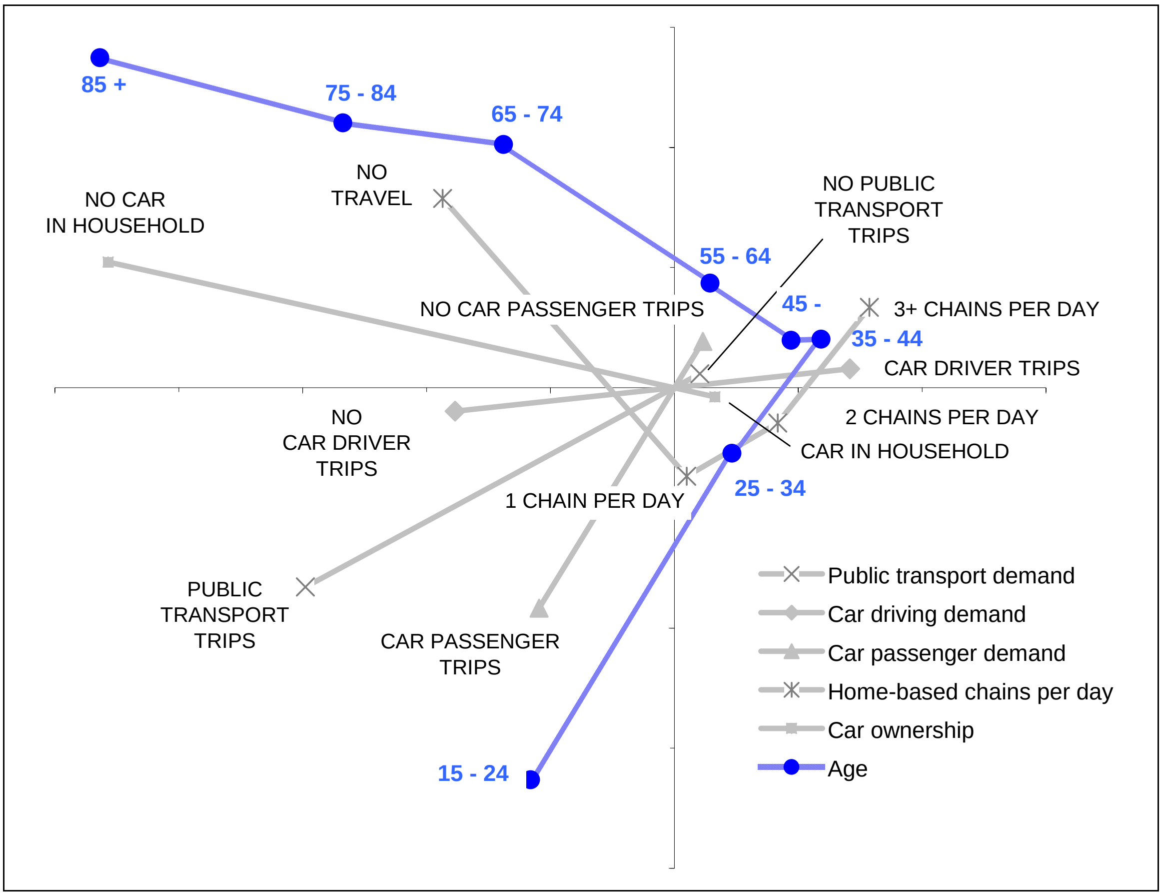

Figure 12: Centroid Category Coordinates for the Five Mobility Variables and Age

3.8 Forecasts

The MCA model can be used for forecasting in much the same way other demand models are used. In all cases, it is necessary to forecast new values of the exogenous variables, followed by estimation of the effects of the exogenous variables on the endogenous variables. Here, we can use future scenarios involving the interacting roles of age, gender and living situation, and income. One scenario is that there will be a reduction in the differences between the upper age categories. In terms of the geometric representation of the MCA solution, this would represent a compression of the age upper portion of the age curve. Another scenario is that women and men living alone will in the future act more like their counterparts living in partnered relationships. Or that the differences between women and men will diminish over time. Finally, we can envision higher incomes for future cohorts of elderly persons. All of these scenarios lead to a consistent set of conclusions discussed in the next section.

4. Conclusions

Policy and planning implications are profound for the role of public transport and the car, as a population ages. Although this might be obvious to many, the extent of the changing modal and trip chain mix as individual's age and the socioeconomic profile changes as the incidence of older age groups increases markedly is not well known. The recognition, empirically, of these age-related modal patterns on travel activity sends an important message about the likely travel behaviour patterns in the future as the population ages. The evidence from a cross-sectional assessment of travel behaviour patterns and driving license trends of each 5-year age grouping in Sydney suggests a number of important points that can assist future policy and planning.

In particular, the preference to maintain car driving remains very strong as individuals age; and although being a car passenger and/or using public transport are available options for many individuals, the absolute growth in trip chains in which car as passenger and public transport are dominant modes is not evidenced by the data. Indeed the potentially misleading inference about the 'popularity' of car passenger and public transport must be highlighted, and is a result of looking at percentage shares of modes in contrast to absolute trip chain activity. The former occurs because of the reduction in car driving, which does not appear to impact significantly on the other modes, suggesting a curtailment of much travel activity.

The curtailment of travel activity has potentially major implications for social exclusion, although further research is required to establish how much of this is compensated by other people visiting the affected persons, what we refer to as reverse mobility of a genuine form of accessibility (where the individual's origin is their destination for a visitor).

The MCA model forecasts a number of key effects of a changing elderly population, although some of these forecasts may cancel out each other. In particular, we predict fewer elderly households in the lowest income quartile (given a positive shift along dimension 1 and a negative shift along dimension 2), implying a higher probability of mobility and higher level of car ownership, resulting in a moderate reduction in public transport use (because of contradictory effects of the two dimensions), and an increase in *both* car passenger and car driver trips. We also predict an increase in income within the upper three quartiles (a positive shift mainly along dimension 1) implying a moderate increases in car ownership, car driver trips and an increase in chain generation for the mobile.

We predict a decrease in the license-holding gap between elderly males and females (a positive shift of females along dimension 1), implying increasing car ownership, a shift in female travel from public transport to car driver, and increasing mobility of the elderly female population

With increased longevity, we predict more couples and less singles in some age groups (due to positive shift on both axes), implying a shift away from public transport and car passenger to an increase in car driver chain generation for the mobile. We also predict a shift along the age curve, implying more zero-car households, more immobility, increased public transport usage, and fewer car driver trips.

Our results provide a useful visualization of what could be gained with repeated cross section data and cohort analyses. Ongoing research should investigate what would be the evidence if we had similar results for repeated cohorts. Would there be systematic shifts in the geometric relationships? For example, is the age curve shifting to the right (or up, or down?). What about gender relationships over time, and couples versus singles? Adding a third – time – dimension to the model is the next obvious step. We do however expect that our predictions in terms of direction of change will hold.

Looking ahead and placing the evidence herein in the context of the wider literature; we promote the view that by and large, the population will age substantially but differ from the elderly of today in certain respects. The elderly will have experienced social change and will be used to claiming their rights, which will foster a more participative form of democracy. Those among the elderly who are not wholly reliant on state pension schemes will enjoy relatively high incomes. They will be car users (drivers or passengers) in the main. A high and increasing proportion of women too will hold driving licences, which is not always the case today.

The death of a husband (typically earlier than spouse) who is the only member of a couple to have a driving licence can pose particular problems. Here, socially inclusive transport solutions will have to be found for people who are still able-bodied but do not drive. So it is important to begin devising solutions that tap the potential of new technologies to rationalise services, especially since conventional public transport is likely to be unable to cope efficiently with an ageing *suburban* population. Walking to bus and train up a steep hill along often uneven streets without footpaths is quite a challenge for many elderly people.

Public transport operators are often unaware of the substantial aging challenge and what it entails. For instance, while public transport signage may be adequate for younger people, it will not be for the elderly. Infrastructure development will have to take into account the large number of elderly people, who are particularly at risk when travelling. It will therefore be important to increase staffing on public transport and at PT interchanges. Encouraging walking (and good diet) at all ages will increase the health of aging people and make alternatives to PT such as the car a longer term mode to give flexible accessibility. However there is a counter view about car dependence encouraging obesity, a factor which reduces mobility and life expectancy. Although flexible public transport systems suited to older passengers are likely to be developed in response to the increasing size and influence of the elderly population, it is unclear whether the new elderly cohorts will view such systems as viable alternatives to the private cars they have been accustomed to using in satisfying their mobility needs

As the number of elderly people in developed economies increases, more individuals are likely to want to continue driving cars as their main means of transport (given their well being and financial status). Manufacturers are likely to respond by making their vehicles easier for older people to drive. To ensure that elderly people can drive safely, there will be pressure on manufacturers to make accommodations in vehicle design, which might include: improved access to seat belts among older people with physical restrictions, improved safety features to protect occupants, pedestrians and cyclists, wing mirrors and other rear view capability given the difficulty in moving one's neck left and right, compulsory power steering, compulsory distance warnings re side swiping, reversing, and parking.

Roads and pavements should be better adapted to the needs of the elderly, including larger signage with less but crucial information (given processing abilities), much better road marking to distinguish lanes, ATIS/ITS signs that assist the elderly in avoiding specific road links and routes that are 'more challenging'.

This paper has focused on the modal and trip chain activity of today's senior and elderly individuals relative to other age groups, as a way of signaling the likely trends in modal and trip chain activity in the future, as a higher proportion of the population move into age groups over 64 years, and especially continue to enjoy relatively healthy and financially strong lifestyles well into their 80's. The mix of evidence from tracking the transport activity in Sydney during the period 2002-2004 and the published literature on the mobility needs of seniors suggests some clear policy and planning directions to service the needs of this growing sector of society. Given the continuing nature of the annual household travel survey in Sydney, we will be in a very strong position to monitor the way in which senior's adapt their travel activity as they age to accommodate their needs and the supply-side opportunities delivered by government and the private sector.

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Appendix

Table A1: Trip Chain Types and Definitions

Trip Chain	Definitions (Study Period is 24 Hours)
Simple Work Car Driver	Only work trips conducted and main mode of travel is car driver
Simple Work Car passenger	Only work trips conducted and main mode of travel is car passenger
Simple Work Public Transport	Only work trips conducted and main mode of travel is public transport
Complex to Work Public Transport	Involves at least one non-work trip or at least one work related trip on the way to or from work and the main mode of travel is public transport
Complex to Work Car Driver	Involves at least one non-work trip or at least one work related trip on the way to work and the main mode of travel is car driver
Complex to Work Car Passenger	Involves at least one non-work trip or at least one work related trip on the way to work and the main mode of travel is car passenger
Complex to from Work Car Driver	Involves at least one non-work trip or one work related trip on the way to and from work and the main mode of travel is car driver
Complex to from Work Car Passenger	Involves at least one non-work trip or one work related trip on the way to and from work and the main mode of travel is car passenger
Complex at Work Car Driver	First destination is work, at least one non-work or work related trip is conducted and a return trip to work is made and the main mode of travel is car driver
Complex at Work Car Passenger	First destination is work and at least one non-work or work related trip is conducted and a return trip to work is made, and the main mode of travel is car passenger
Complex from Work Car Driver	First destination is work and at least on one non-work or work related trip is made, main mode of travel is car driver
Complex from Work Car Passenger	First destination is work and at least on one non-work or work related trip is made, main mode of travel is car passenger
Simple Non-Work Public Transport	One non-work trip is made and main mode is public transport
Simple Non-Work Car Driver	One non-work trip is made and main mode is car driver
Simple Non-Work Car Passenger	One non-work trip is made and main mode is car passenger
Complex Non-Work Public Transport	More than one non-work trip is made and the main mode of travel is public transport
Complex Non-Work Car Driver	More than one non-work trip is made and the main mode of travel is car driver
Complex Non-Work Car Passenger	More than one non-work trip is made and the main mode of travel is car passenger

Source: Adapted from Hensher and Reyes, 2000.

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Figure Legends

Figure 1 Average home-based trip chains per day by age, purpose, and complexity

Figure 2 Average home-based trip chains per day by age and mode

Figure 3 License holding by age, gender and living circumstance

Figure 4 Average number of car passenger home-based trip chains per day by age, gender and living circumstance

Figure 5 Average number of public transport home-based trip chains per day by age, gender and living circumstance

Figure 6 Centroid Coordinates for the Categories of the Three Socio-demographic Variables

Figure 7 Centroid Category Coordinates for Public Transport Demand and the Three Socio-demographic Variables

Figure 8 Centroid Category Coordinates for Car Driving Demand and the Three Socio-demographic Variables

Figure 9 Centroid Category Coordinates for Car Passenger Demand and the Three Socio-demographic Variables

Figure 10 Centroid Category Coordinates for Trip Chain Generation and the Three Socio-demographic Variables

Figure 11 Centroid Category Coordinates for Car Ownership and the Three Socio-demographic Variables

Figure 12 Centroid Category Coordinates for the Five Mobility Variables and Age