An Alternative Measure of Household Structure and Stage in Life Cycle for Transport Modeling

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A. J. Richardson
The Urban Transport Institute
PO Box 363, Alexandra, Victoria, 3714, Australia
Phone/fax number: 61 3 5774 7617
e-mail address: tony.richardson@tuti.com.au

Abstract. This paper introduces a new concept in describing the structure of households. The average age of the household, and its relationship to the age of the individual, is shown to have some interesting and consistent properties which provide greater insight into the structure of households, particularly as an individual grows older. The relationships between age of the individual and average age and size of the household are shown to provide extra information to that contained in more conventional descriptive measures of household structure. In addition, using a CHAID-based model of trip generation, the average age of the household, and its relationship to the age of the individual, is shown to be a more significant predictor of daily trip rates than some more conventional measures of household structure. The paper shows that, despite its computational simplicity, the new variable has promise in describing household structure and changes in life cycle, and that further investigation of the properties of the variable should be undertaken.
INTRODUCTION

Sometimes an idea for a research project comes about through introspection. That is, you think about an aspect of your own life and then generalize it to see whether it holds for a wider population. I can’t remember where I first thought of this idea (probably doodling on an air flight on the way to a conference somewhere) but I found myself calculating the age of my family as I grew from a child to an adult. The tidied-up version of that doodle is shown in Figure 1.

![Figure 1: My Household's Average Age as I Grew Older.](image)

What struck me were the two long stretches of 45° lines, interspersed with some relatively sudden discontinuities. It got me wondering whether other people had similar relationships between their age and the average age of their household members. It then dawned on me that these discontinuities were times of major change in my life. Since I had often encountered the concept of changes in stage of life cycle in transport planning, I wondered whether such relationships, and their discontinuities, could be useful as relatively simple measures of household structure and stage in life cycle. This paper is a first attempt to explore these relationships in a population, and to see whether they might be useful measures of household structure and stage in life cycle in transport modeling and planning.

AVERAGE HOUSEHOLD AGE BY AGE OF INDIVIDUAL

The opportunity to test this concept occurred recently while participating in a study of “Travel Patterns of the Elderly” for VicRoads, the road agency in the state of Victoria, Australia. As a way of examining the way in which the structure of households change as people age, the relationship between the age of the individual and the average age of their household seemed an interesting option to explore. Using data from the 1994 Victorian Activity & Travel Survey (VATS) (1), the average age of each household was calculated and plotted against the age of individuals in each household, as shown in Figure 2.
FIGURE 2 Average Household Age by Age of Individual.

The cloud of data points (from about 17,000 observations) shows three distinct clusters lying roughly on 45° lines. The first cluster for people generally under 30 lies above the line of equality, the second cluster for people generally over 20 lies on the line of equality, while the third cluster for people generally over 30 lies below the line of equality. While Figure 2 shows some regularity to the relationship, the extent of scatter in the raw data masks any specific relationship. The data were therefore grouped to calculate the average household age for each year of age for males and females as shown in Figure 3.
Figure 3 shows a much more regular and meaningful relationship for the population as a whole. When the average person is born, they join a household whose average age (including themselves) is about 20. Over the next 20 years of their life, their household grows by an average of 10 years in age (as younger members join the household and older members leave). Over the next 15 years, from age 20 to age 35, the average person experiences a decrease in the average age of their household (as they leave their familial home to create new households and then start adding new children to this household). A critical event occurs at about age 28, when people start to live in a household that is younger than themselves, rather than a household that is older than themselves. From about age 35 onwards, the average household age increases at slightly more than proportional rate (as children grow up and leave the family home, leaving their parents by themselves). Above the age of 70 the relationship begins to scatter as many different household structures emerge (the elderly couple, the widow or widower living alone, and the extended family where the parents move back in with their children). The above description has concentrated on the conventional nuclear family (which accounts for about 50% of all people). Hidden within this relationship, however, are a multitude of other household types experiencing a variety of changes in stage in life cycle. This variety will be explored more fully later in this paper.

**HOUSEHOLD SIZE BY AGE OF INDIVIDUAL**

A number of other household structure features change as a person ages. One of the more interesting is the size of the household in which a person lives. Figure 4 shows the average size of household for males and females as they grow older. Initially, the average person is born into a household of size 4 (including themselves). This household size increases to nearly five by the time a person reaches about 12 years of age, and then falls to less than three by the time a person reaches about 30. As this person then goes through the family raising stage themselves, the household size increases to nearly four by age 45, then falls consistently as the person grows older until it stabilizes at size two as the person ages beyond 70.
FIGURE 4 Average Household Size by Age of Individual by Gender.

The behavior lying behind the relationship in Figure 4 can be understood more completely by considering the probability of a person living in a specific size household at any age of their life, as shown in Figures 5 through 7. Figure 5 shows that a person does not begin to live alone until they are over 20, and that this percentage increases substantially beyond the age of 60. Above this age, women are more likely to live alone than men, because wives are more likely to live longer than their husbands.

FIGURE 5 Probability of Living Alone by Age and Gender.

Living in a household of two shows two distinct peaks, as shown in Figure 6. The percentage living as a couple increases through the twenties and peaks at an age of about 30. It then declines as these couples start raising families, but then begins to rise again in the forties.
and fifties as children leave home. Over the age of 70, men are more likely to live with one other person than women, as men live with their wives until they die, but women live alone after their husband dies.

### FIGURE 6 Probability of Living in Household of Size 2 by Age and Gender.

The probability of living in a larger household (three, four or five people) rises and falls several times as a person grows older, as shown in Figure 7. Initially, 35% of people are born into a household of size three or four (e.g. they are the first or second child in a two parent family), while only 25% are born into a household of size 5. These probabilities then fall and rise several times as a person ages, but in general the probability of living in a larger family decreases with increasing age of the individual.

### FIGURE 7 Probability of Living in Larger Households by Age and Gender.
The above graphs show that there are systematic relationships between age, gender and household size which capture some of the dynamics of change in household structure as a person grows older.

CONVENTIONAL MEASURES OF HOUSEHOLD STRUCTURE

Many studies that examine the structure of households use a qualitative description of household structure. For example, the 1994 VATS travel survey and the Australian Bureau of Statistics Census use similar descriptions of household structure. The definitions used in VATS are given in Table 1, together with the percentage of households and people living in each household structure, as given by VATS94.

TABLE 1 Household Structure Definitions

<table>
<thead>
<tr>
<th>Household Structure Group</th>
<th>% of Households</th>
<th>% of People</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lone person household</td>
<td>22%</td>
<td>8%</td>
<td>A person living alone</td>
</tr>
<tr>
<td>Single parent &amp; kid(s)</td>
<td>7%</td>
<td>7%</td>
<td>A single parent with one or more children</td>
</tr>
<tr>
<td>Couple without kids</td>
<td>24%</td>
<td>18%</td>
<td>A person and their partner</td>
</tr>
<tr>
<td>Two parent family</td>
<td>34%</td>
<td>51%</td>
<td>A person and their partner, plus one or more children</td>
</tr>
<tr>
<td>Extended families</td>
<td>8%</td>
<td>11%</td>
<td>A group of people living together, including two or more relatives</td>
</tr>
<tr>
<td>Group households</td>
<td>5%</td>
<td>4%</td>
<td>A group of un-related people living together, with no relatives</td>
</tr>
</tbody>
</table>

The changing structure of households as people grow older is shown in Figure 8 for males and Figure 9 for females. It can be seen that more females of all ages tend to live in single parent families, and that major differences between the genders appear in the later years of life. Older males tend to remain in two-person households, while older females tend to be in lone person households and single parent households.

FIGURE 8 Household Structure by Age for Males.
Another question of interest is how the average age of the household varies with the age of the individual for each of the household structures. The relationship for all household structures was shown in Figure 3, and for several of the individual household structures in Figures 10 through 13.

The relationships for single-parent households is shown in Figure 10. For single-parent households, there is a different relationship for males and females above the age of 30.

Whereas the average household age for females in a single-parent household drops sharply for females over 30, the average household age for males over 30 in a single-parent household continues at a much higher level. This reflects two very different types of “single-parent” household. Females over 30 tend to be in single-parent households where they are the parent, whereas males over 30 tend to be in single-parent households where they are the “kid”
and their aged parent is the parent. The consideration of age and average household age has therefore given an extra dimension to the definition of a single-parent household.

The relationship for couples without kids is shown in Figure 11. There are no couples without kids under the age of 20 (at least in the VATS sample), and the relationship above that age is essentially linear with increasing age of the individual. Males tend to live in households with a slightly younger average age, while females live in households with slightly higher average age. This reflects the Australian custom of men marrying slightly younger women (by about 2-3 years).

![Average Household Age by Age of Individual – Couples without Kids.](image)

The relationships for two-parent households are shown in Figure 12. For two-parents households with kids, the relationship is fairly similar to that for all household shown in Figure 3, because two-parent households are the dominant forms of household, especially for younger people as shown in Figures 8 and 9. The transition from living in an older household to living in a younger household is more rapid and concentrated in the years between 25 and 30. In addition, the relationship for older people tends to stay fairly parallel to, but below, the line of equality.
FIGURE 12 Average Household Age by Age of Individual – Two-Parent Families.

The relationships for extended families and group households are shown in Figure 13. The relationships show no major discontinuities or reversals, with group households having a higher slope with increasing individual age than extended families. The relatively flat curves for both types of household may be because of the mixtures of related and un-related people of various ages in the households.

FIGURE 13 Average Household Age by Age of Individual – Extended Family and Groups.

STAGE IN THE LIFE CYCLE

The previous sections have concentrated on household structure as a way of describing the living arrangements of people. However, these household structures are a static way of describing household living arrangements. As people age, they do not stay in the same household structure and move along any one of the curves shown in Figures 10 through 13. Rather they jump from
one household structure to another as they move through stages in the life cycle. For example, for the personal example shown in Figure 1, I moved through several household structures, as shown in Figure 14.

![Figure 14: My Household’s Structure as I Grew Older.](image)

It has been hypothesized that changes in travel behavior are more likely to occur in association with changes in household structure and stage in the family life cycle (2). People are less willing to change their travel behavior if it means disrupting their overall living patterns. However, if they are already undergoing other major changes in living patterns, such as changes in household structure described above plus other major events such as changing house or changing job, then they are less likely to notice changes brought about as a result of changes in travel behavior. Therefore, marketing effort should perhaps be targeted towards those undergoing such external changes.

These changes in household structure can also be identified by means of changes in the average age of the household, as shown in Figure 15 for my personal example. Where my life stage is stable, my household ages one year for every year that I age. Changes in household structure or stage in life cycle are denoted by blips on the graph. Reading from left to right on Figure 15, the blips denote the following changes in household structure:

- Oldest sister leaves home
- Next sister leaves home
- Grandmother comes to live with us
- Grandmother leaves for a nursing home
- Mother dies
- Older brother leaves home
- I leave home to live with friends
- I marry
- My son is born
- My daughter is born
- I divorce and move into flat by myself
- I re-marry
FIGURE 15 Changes in My Household’s Average Age as I Grew Older.

Any of these blips, especially the larger ones, could be significant times when I would have been more willing to consider a change in travel patterns (and in fact did change travel patterns quite significantly). The task for transport market research is to identify these times as they happen; measuring change in average household age from one year to the next is a relatively simple way of highlighting these changes.

MODELS OF TRIP GENERATION

The paper so far has concentrated on describing the relationships between age and average age of the household, and on comparing these measurements with conventional measures of household structure. However, the question remains as to whether any of these factors have an effect on travel behavior. A comprehensive answer to this question would require long and involved analyses. This paper will therefore take just an initial step in this process. The question to be addressed is whether the new measures of household structure (average household age and the relationship between an individual’s age and the average age of their household) make any further contribution to explaining total trip generation per person than the more conventional measures of household structure (household size, household type and individual age).

To simplify the analysis somewhat, a new variable is defined to reflect the relationship between the age of the individual and the average age of their household. This variable is a relative measure that indicates whether a person is living within a household:

- whose average age is younger than themselves (i.e. living in a younger household)
- whose average age is the same as themselves (plus or minus 5 years)
- whose average age is older than themselves (i.e. living in an older household)

The probability of living in one of these types of household, as a function of age is shown in Figure 16. It can be seen that everyone starts out in an older household, but this probability decreases monotonically with increasing age. Initially people move into a household of the same age, then into a younger household, then back into a household of the same age. By the end of...
their lives, people are equally split between households of their own age (mostly males still living with their wives or females living alone) and younger households (females who have moved back to live with their children).

![Proportion of Population within Age Group](image)

**FIGURE 16 Probability of Living with People of Different Ages.**

To test the relationship between trips per person per day and the various measures of household structure described above, univariate relationships were first constructed as shown in Figure 17. It can be seen that males have slightly higher trip rates than females, middle-aged people have higher trip rates than the young and the old, people in larger households have slightly higher trip rates than people in smaller households, people in households with lower average ages have generally higher trip rates than people in households with higher average ages, people who live with younger people have higher trip rates than people who live with older or the same age people, while the relationship of trip rate with household structure shows no clear trends apart from the presence of children in the household increasing the average trip rate.

Univariate relationships, however, do not tell the whole story because of the inter-relationships between the independent variables. For example, both middle-aged people and people who live with younger people are shown to have higher trip rates. However, middle-aged people tend to live with younger people, so it is unclear which factor is producing the higher trip rates. In an attempt to unravel the contribution of each variable to the observed variation in trip rates, the data was analyzed using the CHAID (Chi-squared Automatic Interaction Detector) package (3), which has previously been used in several studies of trip generation (e.g. 4).
FIGURE 17 Trips per Person per Day as a function of various Demographics.
CHAID is a highly efficient statistical technique for segmentation, or tree growing. Using the significance of a statistical test as a criterion, CHAID evaluates all of the values of a potential predictor variables (in this case, the measures of household structure) to determine which variables are the best segmenters of the dependent variable into high and low values. The statistical test used depends on the measurement level of the target variable. If the target variable is continuous, an F-test is used. If the target variable is categorical, a chi-squared test is used. It then merges values that are judged to be statistically homogeneous with respect to the target variable (in this case, the trip rate) and maintains other values that are heterogeneous. It then selects the best predictor variable to form the first branch in the decision tree, such that each node is made up of a group of homogeneous values of the selected variable. The process continues recursively until the tree is fully grown. The growth of the tree can stop when no further splits are statistically significant, when the maximum number of levels on the tree is reached, or when a split would produce a node with fewer observations than a specified minimum. CHAID has the property that the more significant predictor variables are identified first, and that relationships between predictor variables can be identified by having different predictor variables appearing in different branches of the tree.

The CHAID model of trip rates, using the six variables identified in Figure 17 as potential predictor variables, is shown in tree form in Figure 18. Some explanation of this model is warranted. For the entire population of 19,686 people, the average trip rate is 3.25 trips per day (with a standard deviation of 3.08). After searching for all possible segmentations of the data, CHAID found that the most significant split was on the basis of the AGEDIFF variable. Those 13,123 people who lived with older or the same aged people had an average trip rate of 3.02 trips per day with a standard deviation of 2.88, while those 6,563 people who lived with younger people had an average trip rate of 3.69 trips per day, with a standard deviation of 3.40. Of those who lived with older or the same aged people, the next most significant predictor variable was SEX, followed by AVEHHAGE. Of those who lived with younger people, the next most significant predictor variable was AGE, followed by AVEHHAGE, HHSIZE, HHSTRUCT or SEX (depending on the AGE of the person).

The important result that emerges from the CHAID modeling is that, of the household structure variables included in the analysis, the new variables of AGEDIFF and AVEHHAGE appear to be as significant or even more significant predictors of trip rate than the more conventional measures of AGE, SEX, HHSIZE or HHSTRUCT. Certainly, they appear to be better than the HHSTRUCT variable. Given that they are also more easily calculated, they would seem to be useful predictor variables in trip rate models.
### Variables:
- **NUMTRIPS**: Number of trips per person per day
- **AGEDIFF**: Comparative age of household (1=living with older people; 2=living with same age people (within 5 years); 3=living with younger people)
- **SEX**: Gender of individual: 1=Male; 2=Female; -1=missing
- **AGE**: Age in years
- **AVEHHAGE**: Average age of total household
- **HHSIZE**: Number of people in household
- **HHSTRUCT**: Household Structure (1=lone person household; 2=single-parent household; 3=couple without kids; 4=two-parent family; 5=extended family; 6=unrelated group household)

### FIGURE 18 CHAID Model of Trip Generation.
CONCLUSION
This paper has introduced a new concept in describing the structure of households. The average age of the household, and its relationship to the age of the individual, has been shown to have some interesting properties which provide greater insight into the structure of households, particularly as an individual grows older. The relationships between age of the individual and average age of the household have been shown to provide extra information to that contained in more conventional descriptive measures of household structure. In addition, the average age of the household, and its relationship to the age of the individual, has been shown to be more significant predictors of daily trip rates. The paper has shown that the new variables have promise, and that further investigation of the properties of the variables should be undertaken.

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