# Composition of Vehicle Occupancy for Journey-To-Work Trips

Evidence of Ridesharing from the 2009 National Household Travel Survey Vermont Add-on Sample

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## ABSTRACT

Ridesharing serves to mitigate pollution and congestion with minimal investment of public capital while also increasing the efficiency of the transportation system. This research addresses the gaps in the literature on the structure and formation of ridesharing by identifying individual, household, and physical-environment characteristics that correspond with an individual's choice to rideshare instead of drive alone. In order to fully understand ridesharing behavior, there first must be a better understanding of *who* is in the vehicle not just *how many.* A distinction is made between *intra*-household (internal) and *inter*-household (external) ridesharing. Using the Vermont add-on sample of the 2009 National Household Travel Survey, a multinomial logit and nested logit model were developed to examine the determinants of ridesharing. The analysis in this research stresses the importance of how ridesharing behavior can be extracted from survey data. Further, a new method for calculating household vehicle availability is presented, which places less importance on drivers that are not full-time workers. The results indicate that employment density, distance to work and working in small urban area have positive influences on the likelihood of ridesharing. Vehicle availability, age, sex (male), and time spent per trip on the journey-to-work were all found to negatively influence the propensity to rideshare. Cost of travel does not significantly affect ridesharing.

## INTRODUCTION

Continuing growth in vehicle ownership and sprawl has led to dramatic increases in automobile usage. The resulting air pollution, energy expenditure, time consumption, and congestion are significant concerns. Furthermore, the popularity of single occupant vehicle (SOV) trips propagates these problems. The *US National Report on Commuting Patterns and Trends* indicates that the average daily one-way commute trip increased by approximately three minutes between 1990 and 2000, and 13 million solo drivers were added to the US transportation system *(1)*. This can also be seen in the steady loss of the ridesharing market share to driving alone *(2)*. Multiple occupant vehicle (MOV) trips, termed as ridesharing, are one way to increase efficiency of our transportation system, yet little is known about ridesharing behaviors. Even less is available in the literature about structure and formation of rideshares.

The definition of ridesharing takes on several forms throughout the literature, but in general refers to sharing of a personal vehicle by two or more individuals traveling between same or similar origins and destinations. Advantages for rideshare participants include sharing vehicle operation and maintenance costs; being able to use carpool lanes, bypasses, and parking where available; and having travel companionship. Ridesharing is especially advantageous for congestion and pollution mitigation since it makes use of existing infrastructure and does not require extensive investment of public capital *(3)* while also being a viable alternative to other modes of ground transportation *(4)*.

This paper aims to identify factors that influence an individual's decision to rideshare by analyzing travel behaviors with discrete choice models. Using the 2009 National Household Travel Survey (NHTS) Vermont add-on sample, the relationships between various travel behavior determinants (e.g., travel time and length, socio-demographics, and spatial characteristics) and the propensity to rideshare on the journey-to-work are explored. Socio-demographic variables considered were gender, age, total household income, household size, number of drivers, and household automobility. Household automobility is a relationship between total number of vehicles with respect to the number of workers and registered drivers in a household. Spatial variables include employment density surrounding the workplace, household density surrounding the residence, stated distance and time traveled to work, and calculated shortest path distance to work. A distinction was made between *inter*-household (external) and *intra*-household (internal) ridesharing to consider how different factors may influence the formation of each MOV type. The nature of vehicle occupancy will be referred to herein as "composition of vehicle occupancy" (CVO). More specifically, vehicle occupancy refers to *how many* people are in the vehicle whereas CVO refers also to *who* is in the vehicle.

Further analysis suggests that certain variables serve as significant predictors of ridesharing likelihood. Multinomial Logit (MNL) and Nested Logit (NL) models were developed to help explain the utility of ridesharing for respondents in the survey dataset. This research is limited by the absence of travel cost and attitudes towards rideshare participation in the NHTS data.

## DEFINING A SHARED RIDE

Ridesharing or carpooling take on numerous definitions throughout the literature and slight modifications create ambiguity that affect the way these behaviors are extracted from travel data.

Current definitions are discussed and a new method for defining vehicle sharing behavior is presented to facilitate data extraction consistency. Hunt and Macmillan *(5)* broadly defined carpooling as any instance where more than one person was in a vehicle, whether or not there was any formal arrangement and marked differences between *regular* and *occasional* carpools. Regular carpools are considered to be those that are scheduled and on a recurring basis (or at least a few times a month with someone who he or she did not live with) while occasional carpools are those that are situational only *(6, 7)*.

Minimal research exists on CVO in rideshares. Ridesharing composition refers to whether the carpool had an internal structure (i.e., riders are members of the same household) or an external structure (i.e., riders are from different households). Teal *(8)* noted that external carpoolers comprised 58% of the entire carpool sample from the 1978 Nationwide Personal Transportation Survey, while 40% were internal carpoolers. Internal carpooling has also been referred to as "fampooling" *(9)*. A study of the 2001 NHTS indicated that carpooling is much more prevalent amongst immigrants than non-immigrants *(10)*. Further, the same study found that internal carpooling is much more influenced by the amount of time one has been in the country than is external carpooling. With declining amounts of *inter*-household ridesharing and *intra*-household ridesharing now comprising a more significant portion of the market, it is expected that commute trip reduction programs would not likely lead to large regional reductions in vehicle trips *(11)*. This illustrates the importance of making a distinction between MOV types.

Care must also be exercised when defining the way in which ridesharing information is extracted from the NHTS dataset or other travel data. For example, when considering ridesharing and commuting to work, one may simply extract trips identified as having work as the destination and then filter by vehicle occupancy. This kind of approach, however, could lead to a gross underestimation of ridesharing occurrences since a person's journey-to-work may include multiple trips chained together and the passenger is dropped off before the final destination.

Ridesharing encompasses all forms of MOV travel and includes formations that extend out to broader networks with different means of connectivity (e.g., online databases or other social networks) which includes the unique form of "slugging" where strangers are picked up informally in order to utilize high occupancy vehicle lanes. Carpooling, a subset of ridesharing, is considered to be organizing a ride with another person through some direct network (e.g., a household or workplace) which inherently means that there is a shared origin and/or destination. Fampooling would then be a subset of carpooling since riders share a common origin. Chauffeuring would be specific to instances where the passenger is unable to drive (e.g., is too young to have a driver's license or has a condition that limits or restricts driving ability).

In this study, only journey-to-work rideshares are considered and ridesharing in this context was defined as having more than one person in the vehicle at any point before arriving at the work destination. A further distinction of ridesharing is made when the composition of the riders is either strictly made up of members from the same household (i.e., *intra*-household ridesharing), regardless of relations, or individuals from different households (i.e., *inter*-household ridesharing) both of which may include chauffeuring.

## LITERATURE REVIEW

Research surrounding an individual's choice to carpool suggests that formation and use is particularly sensitive to socio-economic characteristics (e.g., gender, age, and income), ability to be matched with other carpool users, mobility status (e.g., the number of household automobiles available), value of time, and attitudes toward cost and environment *(3)*. It has also been proposed that the decline of carpooling during the mid-eighties was in direct response to social and demographic changes in the commuting population and the evolution of urban form designed with SOV in mind *(12)*.

The personal vehicle can be regarded as an expression of an individual's social status, and not just a means of conveyance. Carpooling melds the space-saving characteristic of public transportation while retaining the advantages of an automobile *(11)*. Nevertheless, many people are hesitant to carpool for different reasons. One may expect that carpooling generally requires more travel time (unless the origin and destination are the same for everyone in the vehicle) and reduces flexibility in travel due to demands of meeting different, possibly conflicting, schedules. Perceptions of carpooling (e.g., constraints on independence, social requirements and interpersonal rapport) have also been found to play a larger role than cost or convenience *(13)*. For some, the anonymity of using transit is more appealing than the induced social climate of carpooling *(7)*.

Negative relationships have been established with income and access to household vehicles and positive relationships with number of workers in the household and trip length *(7, 12-14),* yet income is thought to have an indirect effect on carpooling where it directly affects automobile ownership *(13).* Some researchers maintain that socio-demographic characteristics only play a small role in the choice to carpool *(7, 15)*. Hartgen *(16)* suggests that vehicle availability is a more important determinant and that educational attainment plays a larger role than other socio-demographics. The relationship between work-trip ridesharing and demographics have been identified as being extremely weak *(17)*, and the contradiction to Buliung *(3)* suggests that further research is needed on work-trip ridesharing.

Carpooling has also been found to have a negative relationship with residential density and metropolitan size; this is attributed to dense and larger urban areas having better established public transit services *(7, 13, 18)*. Other studies have suggested that residential density (households per acre), employment density (employees per acre), and mixed land use have strong influences on not only mode choice but the probability of commuting by personal automobile *(19-22)*. More specifically, employment density and spatial characteristics (e.g distance to a central business district and industrial area percentage) at the workplace are found to have correlations with work commute mode choice *(23, 24)*.

Carpool users tend to travel further than SOV drivers, indicating that the choice to carpool is driven by location and destination *(8)*, and that carpooling becomes appealing at a travel distance of 10 miles *(25)*. The attractiveness of carpooling is also positively correlated with the number of household workers (suggesting that internal carpooling became more likely) and negatively correlated with the ratio of vehicles to licensed drivers *(26)*. Gender, multiple worker households, commute length, and workplace size have been found to correlate with frequency of ridesharing *(12)*. Even with apparent links between these variables and carpooling, attitudes about the environment and pro-social concerns have strong influences on carpooling propensity *(27)*. Trip type, trip length and land use are variables that have considerable contradiction in the literature surrounding rideshare modeling and will be examined in this research.

## DATA AND METHODOLOGY

The 2009 NHTS is the most recent comprehensive survey regarding personal travel in the United States. It allows for analysis of daily travel by all modes used by the respondents and includes information on characteristics of the people traveling, their household, and their vehicles. For Vermont, a predominantly rural state with sparse population, an over sample was purchased to ensure a robust sample size. The Vermont sample was used in this research because geocoded household locations were available in the survey and the availability of other geographic information system (GIS) data. The findings can be expected to have transferability to other areas that are primarily rural and have low population densities with small urban areas. The Vermont add-on sample includes 1690 households, 3550 individuals, and represents a sampling rate of 2.1% compared to the national average of 0.4%. The version of data analyzed was the November 2010 release and also includes updated household and work geocoded locations released in June 2011.

### Methods

The purpose of this research is to broaden the understanding of rideshare formation and identify factors influencing this phenomenon. To this end, a mode choice problem is developed to consider how commuters choose between driving alone and either participating in an *intra-* or *inter*-household rideshare. Only respondents who have at least one vehicle in the household were included so each individual in the dataset would have the option to drive alone. Since the research question here regards ridesharing – more generally, the nature of *vehicular* use on the drive to work – the dataset was limited to respondents who made a trip from home to work by automobile as either a driver or passenger with non-zero distance. The intent was to examine individuals who have access to a personal vehicle and choose to rideshare on their journey-to-work.

The dataset was filtered to remove individuals who had null data for home and workplace locations as well as distance and time to work. The final dataset included 873 individuals, 336 of whom shared a ride (129 *inter*-household and 207 *intra*-household) on at least one trip segment of their journey-to-work.

A number of variables were extracted from the dataset or calculated with a priori knowledge from the literature review. Descriptive statistics of the variables retained for use in the discrete choice model are shown in Table 1. Also presented are results of the chi-square and t-test analysis which indicated variables likely to have a significant contribution to the discrete choice model.

**Table 1** Descriptive statistics of variables considered for the discrete choice model

| Variable | Drive Alone *(N=537)* | | Rideshare (Intra) *(N=207)* | | Rideshare (Inter) *(N=129)* | |
|---|---|---|---|---|---|---|
| | Mean | Std Dev | Mean | Std Dev | Mean | Std Dev |
| Age *(years)* [a,c] | 49.2 | 12.6 | 44.5 | 11.7 | 44.2 | 14.1 |
| Female *(dummy)* [a,d] | 0.47 | | 0.57 | | 0.56 | |
| # of HH drivers [b,d] | 2.17 | 0.71 | 2.33 | 0.82 | 2.14 | 0.88 |
| # of HH workers [a,c] | 1.80 | 0.67 | 1.99 | 0.75 | 1.86 | 0.77 |
| # of vehicles in HH [c,b] | 2.55 | 1.07 | 2.45 | 1.02 | 2.43 | 1.22 |
| HH vehicle availability [c,b] | 1.41 | 0.61 | 1.23 | 0.55 | 1.30 | 0.62 |
| Cost of travel is most important travel issue *(dummy)* | 0.35 | | 0.40 | | 0.34 | |
| Time to work *(minutes)* | 22.67 | 16.48 | 20.49 | 15.51 | 20.98 | 17.15 |
| Distance to work *(miles)* [a] | 13.64 | 12.79 | 11.91 | 11.12 | 12.13 | 10.68 |
| Employment density around workplace *(jobs per square-mile)* [a,c] | 1961 | 2481 | 2690 | 3461 | 2203 | 3131 |
| Housing density around home *(HH per square-mile)* [b] | 525 | 1137 | 729 | 1504 | 705 | 1249 |

Notes: $^{a}p < 0.01$, $^{b}p < 0.05$ for t-test between driving alone and ridesharing
$^{c}p < 0.01$, $^{d}p < 0.05$ for chi-squared analysis between drive alone, *intra*-household ridesharing and *inter*-household ridesharing

Source: 2009 NHTS

Drive alone was considered available to everyone in the choice set since the data were limited to only individuals who reside in a non-zero vehicle household. *Inter*-household ridesharing was considered to be available for everyone in the sample; it is assumed that if one owns a vehicle, then there will always be the possibility of asking someone to ride as a passenger or leave one's vehicle at home and ask to ride with another person. *Intra*-household ridesharing was considered to be available if there was more than one working adult in the household, where adult is defined as an individual who was of driving age. It should also be noted that for simplicity of the model, the case when *intra*-household and *inter*-household ridesharing are happening concurrently (i.e., there are passengers in the vehicle from both their own household and another household) is considered to have more in common with *inter*-household ridesharing and are included with those cases herein. Availability for this case was considered to be the same as *intra*-household ridesharing. In the Vermont NHTS dataset of workers who commuted by automobile, the market share of driving alone is 61% (*inter*-household and *intra*-household ridesharing account for approximately 15% and 24%, respectively).

Sixty percent of all ridesharing in the NHTS sample were *intra*-household shared rides, a more even split than findings by Blumenberg and Smart *(10)* using the 2001 NHTS and Ferguson *(13)* using the 1990 Nationwide Personal Transportation Survey. This is thought to be attributed to the way in which shared rides were extracted from the data and that only journey-to-work trips were being analyzed. This eliminated many of the “chauffeuring-type” ridesharing trips that occurred on tours, did not include a work trip, and were likely to be primarily *intra*-household in nature.

Household Vehicle Availability (HHVA), shown in Equation 1, is defined as the number of vehicles available in the household divided by the sum of number of workers in the household and one-quarter of the difference between number of drivers and number of workers in the household (vehicle need). This is a novel approach for calculating HHVA. Past research tends to look at vehicle availability as a ratio of personally owned vehicles to drivers in the household without a greater importance being placed on the workers in the household. The distinction of available versus non-available is typically marked at one vehicle per driver *(23, 24)*.

$$HHVA = \frac{Vehicles}{Workers + 0.25\ (Drivers - Workers)} \qquad \text{Equation 1}$$

The assumption being made here is that if there are more *drivers* than *workers* in the household, the “extra” drivers are not full-time worker status and would, therefore be in less need of and place less importance on using a vehicle. Dalirazar *(28)* indicates that approximately one-quarter of individuals report “taking care of children/others” as being the main reason for not working. A coefficient of 0.25 is used to retain vehicle need for this proportion of non-working drivers. Limited refers to a ratio less than 1.0, moderate vehicle availability is greater than or equal to 1.0 but less than1.5, and unrestricted is anything greater than or equal to 1.5. Figure 1 depicts the increase in the percentage of individuals ridesharing for households with limited vehicle availability, with more of these individuals opting for *intra*-household ridesharing. Driving alone becomes more prominent when approaching unrestricted vehicle availability.

A dummy variable was created to reflect if price of travel was the respondents’ most important transportation issue. Age was transformed into a dummy variable reflecting if the respondent was 40 years of age or older, which is based on past research suggesting that while mobility of individuals peaks when they are in their 30s, transportation expenditures peak in their 40s *(12, 29)*. A dummy variable was also included to indicate the sex of the respondent. Lastly, a dummy variable was created to indicate whether or not the individual worked in Chittenden County (the only metropolitan planning organization in the State of Vermont).

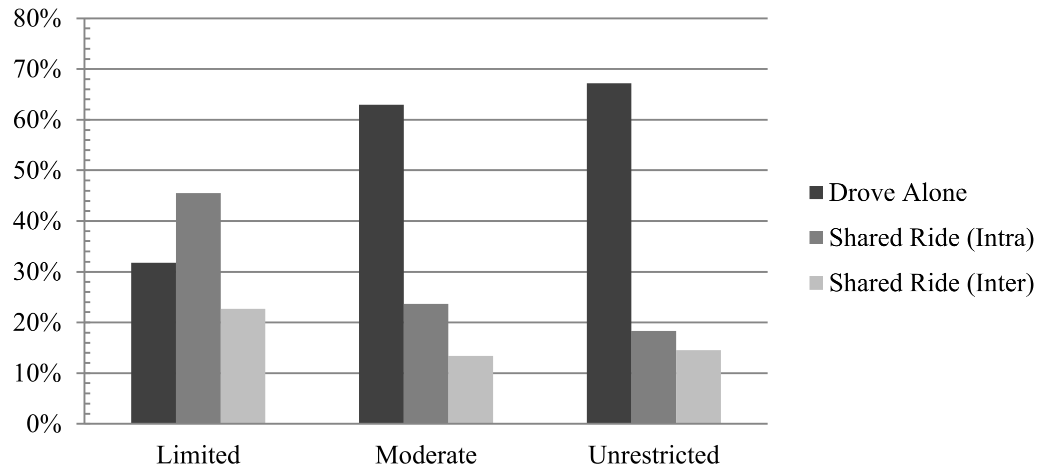


**FIGURE 1** Market share of CVO by household vehicle availability

### Residential Density and Employment Density

The 2009 NHTS dataset includes specific geographic information regarding the individuals' household and work locations specified by latitude and longitude. This information was combined with information available from the Vermont E911 database and a business location database using geographic information systems (GIS) processing to allow for extremely accurate measures of employment and housing densities. Residential density values were determined at the respondents' home location by summing the number of housing within a one-mile radius. Similarly, employment density was calculated by summing number of jobs within a one-mile radius of the respondents' workplace. It is expected that higher residential densities and business densities would provide more opportunities for a person to find a ridesharing "opportunity" or match.

### Travel Time and Distance to Work

Similar to work by Witlox *(30)*, the relationship between a respondent's stated distance and shortest path distance between home and work was examined, which can help show how much further people who rideshare deviate for passenger accommodation. Figure 2 shows relationships between stated and shortest path distances for drive alone, *intra*-household and *inter*-household modes. This illustrates that respondents are not deviating much from their shortest-path and suggests that origins and destinations (or diversions) must be close to a typical work travel route in order for ridesharing to be appealing. This is similar to the findings of Li et al. *(9)* who found that the additional time incurred from carpool formation was only five minutes on average, attributed in part to the high rate of fampooling and inherrent time savings from high occupancy vehicle lanes. The average deviations, expressed in the r-squared values, between stated versus shortest path distances are greater for *intra*-household and *inter*-household ridesharing as compared to driving alone; this is considered to be indicative of deviations from the shortest path. However, it is important to recognize a few limitations: First, some portion of these deviations may be the result of poorer judgment of distance by rideshare passengers.

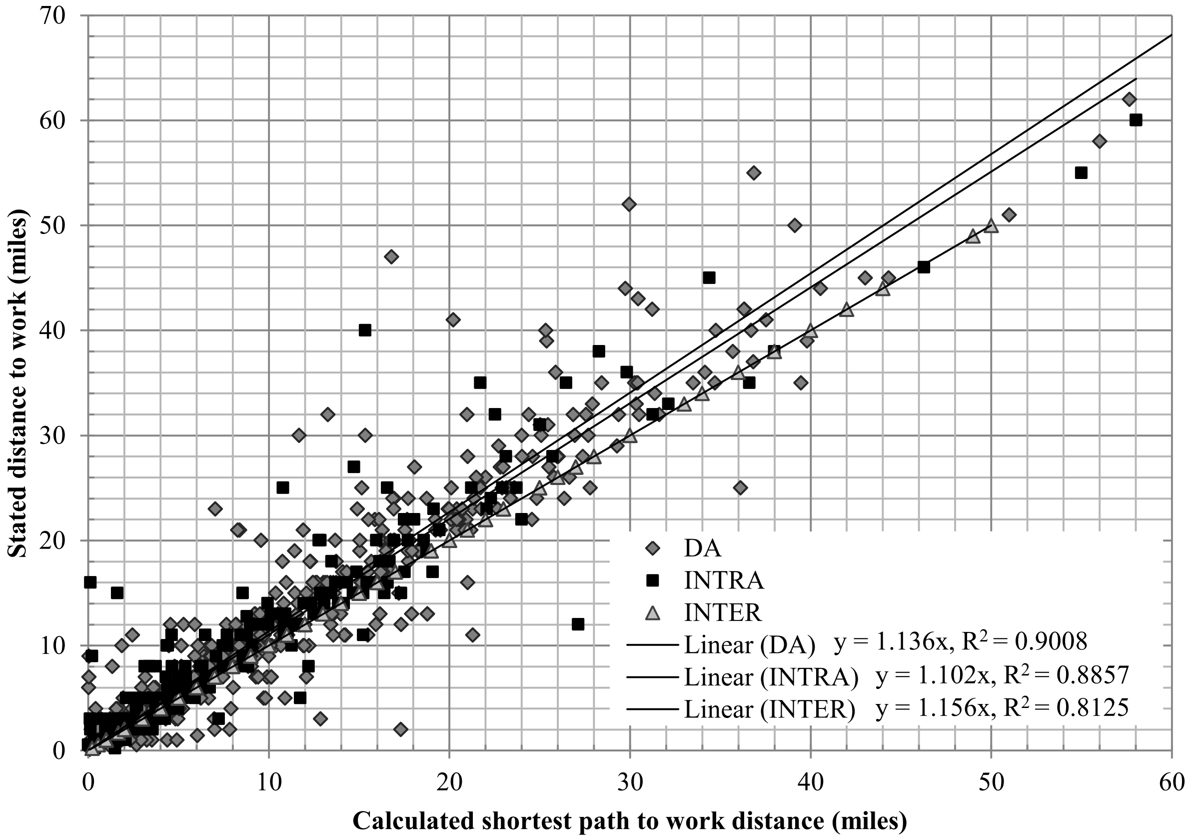


**Figure 2** Stated distance versus shortest path distance by CVO

Second, stated distance to work will always remain constant (i.e., a persons' typical route) but the actual distance could have day-to-day variations due to participation in different activities. Lastly, values of time exceeding ten minutes are typically reported in five-minute intervals – likely imparting a small amount of rounding bias to the dataset. Similarly, distances to work values were often reported in five-mile increments over a distance of 20 miles.

In order to examine these differences further, the travel distance to work was broken down into five distance classes. A diversion factor ($DF_{dm}$) was calculated as the ratio of stated distance to shortest path distance (Equation 2 and values shown in Table 2). Note that the largest differences between modes exist in the less than four mile distance class with both *inter*-household and *intra*-household diversion factors being approximately twice that of the drive alone diversion factor. Distance classes were chosen so that there would be close to an equal number of respondents in each distance class within modes. These calculations are used to formulate a factor (${MF_d}^{(nc)}$) to estimate distance traveled for the non-chosen alternatives (as shown in Equation 3) which is the diversion factor for each non-chosen alternative (${DF_d}^{(nc)}$) divided by the diversion factor for the chosen alternative (${DF_d}^{(c)}$) in each respective distance class $d$.

$$DF_{dm} = \frac{\sum_{k\epsilon K_{dm}} SD_k}{k} \Big/ \frac{\sum_{k\epsilon K_{dm}} MIN(PD_{ij})_k}{k} \qquad \text{Equation 2}$$

$$MF_d{}^{(nc)} = {DF_d{}^{(nc)}} \Big/ {DF_d{}^{(c)}} \qquad \text{Equation 3}$$

where:

$K_{dm}$ is the set of respondents whose stated distance is in range *d* for each trip mode *m*

$SD_k$ is the stated distance of respondent *k* in distance class *d*

$MIN(PD_{ij})_k$ is the shortest-path-distance from origin *i* to destination *j* for respondent *k* in distance class *d* for the chosen alternative *c*

$DF_d{}^{(nc)}$ is the diversion factor for each non-chosen alternative *nc* in distance class *d*

$DF_d{}^{(c)}$ is the diversion factor for the chosen alternative *c* in distance class *d*

For example, the alternative specific distance-to-work variable was created for the non-chosen *intra*-household alternative for someone who drove alone less than four miles to work would be 1.86 times the stated distance traveled (2.62 divided by 1.41). Note that in two of these cases the deviation factor is slightly larger for the drive alone case than the ridesharing cases, but is thought to be minimal enough as to not have an effect on the model.

The stated time and stated distance to work were examined to determine "time penalties" for choosing to rideshare. Linear regression plots of stated time versus stated distance for each mode are presented in Figure 3 which illustrates that, in general, individuals choosing to rideshare spend more time covering the same distance as someone who drives alone. For example, a person who travels 20 miles to work would spend 31 minutes if driving alone, 33 minutes if *intra*-household ridesharing, and 34 minutes if *inter*-household ridesharing. This corresponds with analysis results of the stated versus shortest path distances in which distance penalties diminish as distance to work increases and time penalties increase as distance to work increases. This is assumed to be an accurate reflection of the extra time required to pick up and drop of an individual who is not a member of the same household. The extra time incurred for *intra*-household ridesharing is considered to be less than that for *inter*-household ridesharing because the ridesharing members have a common origin.

**Table 2** Diversion factors of stated distances

| Distance Class (miles) | *N* | Mean | | Deviation Factor |
|---|---|---|---|---|
| | | Stated Distance (SD) | Shortest Path Distance (SPD) | SD/SPD |
| Drove Alone | | | | |
| <4 | 91 | 3.78 | 2.69 | 1.41 |
| 4 – 7 | 121 | 5.24 | 4.74 | 1.11 |
| 7.1 – 12 | 118 | 10.19 | 8.94 | 1.14 |
| 12.1 – 21 | 93 | 16.81 | 14.57 | 1.15 |
| >21 | 113 | 33.42 | 28.04 | 1.19 |
| Shared Ride (Intra) | | | | |
| <4 | 50 | 4.54 | 1.74 | 2.62 |
| 4 – 7 | 39 | 5.26 | 4.87 | 1.08 |
| 7.1 – 12 | 46 | 10.30 | 8.81 | 1.17 |
| 12.1 – 21 | 40 | 16.14 | 13.77 | 1.17 |
| >21 | 32 | 32.75 | 27.62 | 1.19 |
| Shared Ride (Inter) | | | | |
| <4 | 30 | 4.23 | 2.03 | 2.08 |
| 4 – 7 | 27 | 5.48 | 4.94 | 1.11 |
| 7.1 – 12 | 26 | 10.12 | 8.48 | 1.19 |
| 12.1 – 21 | 21 | 16.71 | 14.68 | 1.14 |
| >21 | 25 | 31.36 | 24.60 | 1.27 |

**Model Specification**

A multinomial logit (MNL) model was developed to examine the influence of variables shown in Table 1 and Table 2 on CVO. This model assumes that the likelihood of selecting one CVO over another remains unchanged regardless of the availability of alternatives and that the choices are not substitutes for one another, known as irrelevance of independent alternatives (IIA). Although though the MNL model was found to not violate the IIA property, a nested logit (NL) model was also developed to test whether the two ridesharing alternatives (*intra*-household and *inter*-household) have enough in common to be grouped under a single rideshare nest. The top-level of the nesting structure differentiates between driving alone and ridesharing and the bottom-level accounts for the two ridesharing types. The MNL and NL model structures are depicted in Figure 4. A respondent was determined to have driven alone if their journey-to-work had no other individuals in their car. *Intra*-household ridesharing was regarded as chosen by the respondent if the occupants of the vehicle on the journey-to-work were comprised only of individuals from the same household. *Inter*-household ridesharing was considered chosen by anyone who rode in a vehicle with another occupant not from the same household. The mixed-form of a shared *inter*- and *intra*-household ridesharing structure was considered to have enough commonality with *inter*-household ridesharing that a separate category was not necessary.

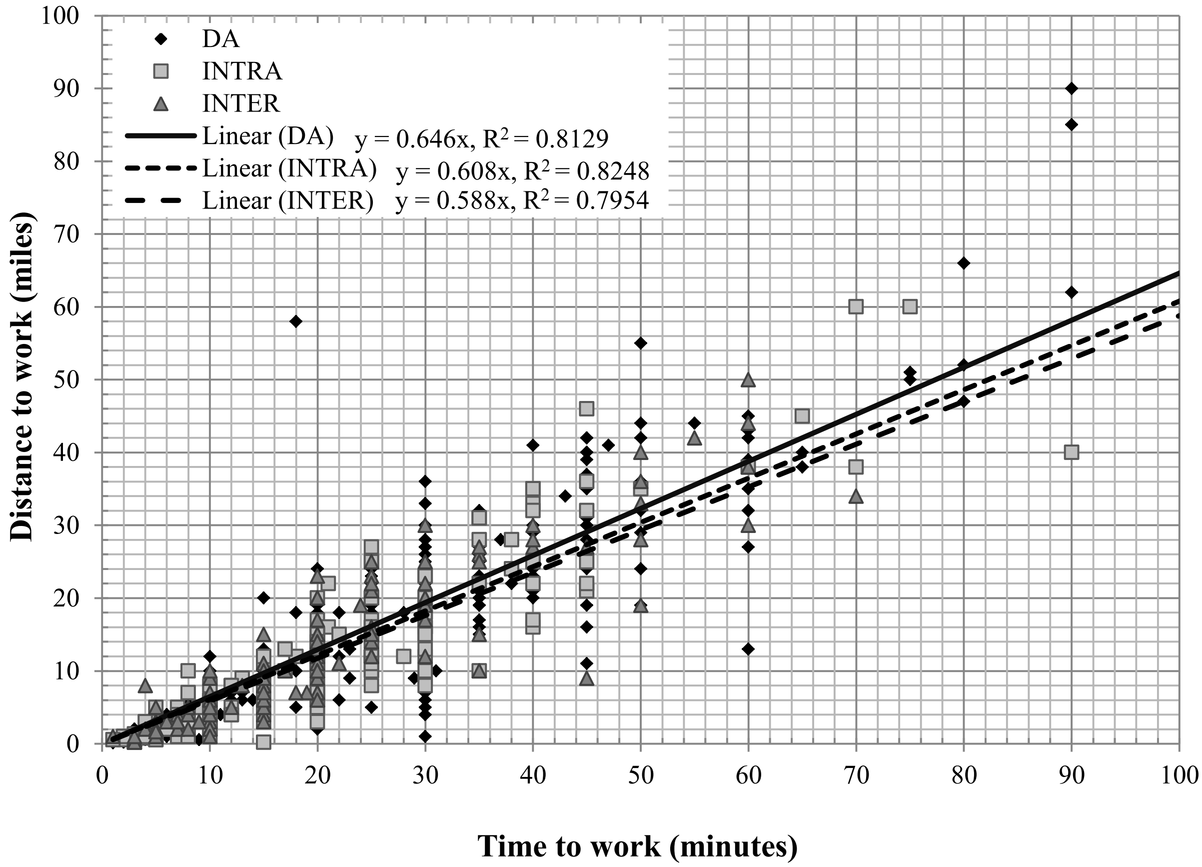


**Figure 3** Stated time versus stated distance to work by CVO

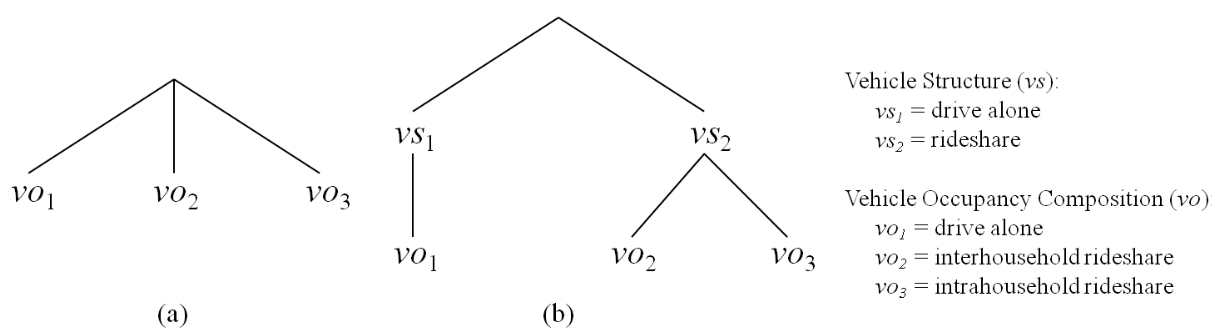


**Figure 4** (a) Single-tier and (b) two-tier nested structure for composition of vehicle occupancy

The drive alone mode was set as the reference alternative for the discrete choice analysis for three reasons: 1) it was the most widely available alternative to each individual; 2) the market share of driving alone was observed to be notably higher than that of ridesharing; and 3) each household in the selected sample owns at least one vehicle so everyone has the option of driving alone.

Before including the time-to-work variable in the model, it was normalized by number of stops on the journey-to-work. While the distance-to-work and time-to-work variables are highly correlated, number of stops on the journey-to-work and distance-to-work are not. Using time per trip allows the model to consider the "effort overhead" *(31)* of the journey-to-work that is not directly proportional to length. The rationale is that there is a distinct difference between someone who spends a certain amount of time traveling to work because they ran a number of "errands" on their way and someone who spends the same amount of time but went directly from home to work. This variable was calculated by dividing stated time-to-work by number of trips made on the home-to-work portion of their travel day tour.

## MODEL RESULTS

The model results (shown in Table 3) indicate that all else being equal, one prefers to share a ride with someone from the same household, but favors driving alone to sharing a ride with someone from a different household other than their own (as indicated by the alternative specific constant). Females are more likely to rideshare than males. This supports other research that women tend to participate in carpools more than men *(10)*. Individuals working in areas with higher employment densities are also more likely to rideshare. This fits with the expectation that there are more opportunities to find a rideshare candidate in areas where people work more closely together. Individuals working in Chittenden County have a higher propensity to rideshare. Chittenden County has the highest employment densities in the state, suggesting something other than just proximity of jobs in small urban areas influences ridesharing. This is supported anecdotally by a higher presence of rideshare lots and the challenges (e.g., costs) and availability of parking when comparing Chittenden County with other counties in the state.

Housing density appears to have some relationship with ridesharing, but does not lend a significant contribution to the discrete choice model. This implies more importance is being placed on the destination (i.e., work) end of the trip and likely means that those who are *inter*-household ridesharing care more about sharing proximal work locations than proximal housing locations.

Ridesharing is less likely for individuals that are 40 years of age or older. These individuals also have a slight preference for *intra*-household ridesharing over *inter*-household ridesharing which fits with expectations and literature that older drivers are likely to be more set in their established commute patterns. The utility of ridesharing also decreases as household vehicle availability increases. This is interpreted as diminished motivation in rideshare coordination when concern for access to household vehicles does not exist.

The time variable indicates that the likelihood for both *inter*-household and *intra*-household ridesharing will decrease as travel time per trip on the tour to work increases. Conversely, the distance variable indicates that ridesharing is more likely as distance to work increases. One interpretation is that there are a number of individuals having long (i.e., time) but not necessarily lengthy (i.e., distance) commutes to work, whereby the user is more sensitive to changes in time. Coupled with this is the idea that lengthy commutes will always be long (relatively speaking) and thus time is inherently considered with length. Hence, there is a need to utilize a time metric in conjunction with the distance variable in order to account for this. The significance of the time variable in the model reinforces this hypothesis.

**TABLE 3** Best-fit model estimation results

| | MNL Model | | NL Model | |
|---|---|---|---|---|
| Variable | β | p-value | β | p-value |
| *Drive Alone* | *(Base Alternative)* | | *(Base Alternative)* | |
| *Rideshare Alternative* | | | | |
| Gender *(base female)* | -0.279 | 0.07 | -0.280 | 0.07 |
| Works in Chittenden County | **0.527** | 0.00 | **0.528** | 0.00 |
| Employment Density *(jobs/1000)* | 0.037 | 0.17 | 0.037 | 0.17 |
| *Inter-household Rideshare Alternative* | | | | |
| Alternative Specific Constant | -0.371 | 0.32 | -0.215 | 0.72 |
| Time-to-work/#Trips *(minutes/trip)* | **-0.162** | 0.00 | **-0.167** | 0.00 |
| Distance-to-work *(miles)* | **0.046** | 0.00 | **0.048** | 0.00 |
| Household Vehicle Availability | -0.154 | 0.41 | -0.172 | 0.36 |
| Age 40+ | **-0.718** | 0.00 | **-0.728** | 0.00 |
| *Intra-household Rideshare Alternative* | | | | |
| Alternative Specific Constant | 0.575 | 0.07 | **0.600** | 0.05 |
| Time-to-work/#Trips *(minutes/trip)* | **-0.233** | 0.00 | **-0.227** | 0.00 |
| Distance-to-work *(miles)* | **0.071** | 0.00 | **0.068** | 0.00 |
| Household Vehicle Availability | **-0.454** | 0.01 | **-0.437** | 0.02 |
| Age 40+ | **-0.620** | 0.00 | **-0.621** | 0.00 |
| Rideshare nesting coefficient ($\mu_m$) | *(n/a)* | | 0.870 | 0.76 |
| Observations (N) | 873 | | 873 | |
| Final Log-Likelihood | -707.09 | | -707.01 | |
| Null Log-Likelihood | -929.32 | | -929.32 | |
| LL Ratio (ρ) | 0.239 | | 0.239 | |
| Adjusted ρ (ρ') | 0.225 | | 0.223 | |

*Note: bolded coefficients indicate statistically significant variables*

Lastly, nesting ridesharing alternatives together with drive alone as its own nest did not result in any model improvement. The estimated logsum parameter ($\mu_m$) for the rideshare nest is relatively large at 0.87 which suggests that *inter*-household and *intra*-household ridesharing do not share enough characteristics in common to be combined in a hierarchical NL model structure. Although the two ridesharing alternatives are similar with regard to MOV, the nature of riding with someone from your household is quite different from riding with a person from another household which requires establishing personal relationships. Coordinating rides and sharing vehicles also becomes much more difficult when *inter*-household ridesharing.

## CONCLUSIONS

The findings support the initial hypothesis that demographic, spatial, and automobility characteristics influence the composition of vehicle occupancy. The results of the discrete choice analysis developed here align well with the previously documented research on the journey-to-work mode choice. Several household, individual, and trip characteristics were found to have a significant effect on the composition of vehicle occupancy during the journey-to-work. Individuals working in higher employment densities are more likely to rideshare – with a slightly greater tendency for *inter*-household ridesharing than *intra*-household ridesharing as the distance to work increases. This supports past research suggesting that land use at the work-end of a trip has the most influence on mode choice, and confirms that this influence plays a significant role in rideshare formation. The likelihood of ridesharing decreases as the average time spent per trip on the journey-to-work increases and has a stronger influence on *inter*-household ridesharing, providing an indication that a relationship exists between ridesharing likelihood and presence of trip-chaining during the journey-to-work. Individuals over the age of 40 are less likely to rideshare compared to the younger population, with a preference for *intra*-household ridesharing over *inter*-household ridesharing. Ridesharing is also more likely for females and individuals working in a metropolitan planning organization (Chittenden County).

Ridesharing becomes less likely as household vehicle availability increases. This research also presents a new method for calculating vehicle availability which places less importance on drivers that are not full-time workers. This variable was found to have greater statistical significance than using only household size and automobile ownership. This has potential for contributing to future research concerning vehicle need of home-makers and allocation of vehicle usage to teen drivers. Cost of travel does not appear to be a motivating factor for ridesharing, which is interesting since it is expected that a person might rideshare to reduce their overall travel cost (i.e., split the cost with another person), and suggests further research is needed on the role of monetary incentives and rideshare formation.

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