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Investigating Household Level Trip Sharing: a Case Study of Future Car Sharing and Autonomous Vehicle Adopters in Australia

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Abstract

Alternative mobility solutions such as car sharing, autonomous vehicles (AVs) and shared autonomous vehicle (SAVs) may potentially reduce private vehicle use and increase trip sharing. These solutions are likely to transform current travel experiences and have significant impacts on future travel decisions. Previous studies have investigated future mobility needs and travel patterns by focusing on people's stated preferences regarding car sharing, AVs, and SAVs in various scenarios. In this study, we propose that exploring existing travel behaviour such as trip sharing may improve our understanding of future mobility decisions. One aspect of travel behaviour that may yield insights into future demand for shared travel is to examine household level trip sharing. With this explicit aim, this study makes use of survey data that includes trip sharing information collected from Australian households in 2016. This study investigates the travel decisions of household members who reported that they participate in car sharing programs, are early technology adopters, or potential future AV owners. Discrete choice models were estimated to understand the trip sharing decisions that households make when sharing trips with other household members. Household members who would purchase AVs in future are more likely to share trips with two or more household members. Similarly, self-reported early technology adopters tend to have relatively higher trip sharing rates. In contrast, car sharing users, active or public transport users have less tendency to share trips with other household members.

Keywords: trip sharing; household travel behaviour; autonomous vehicle adopters; technology adopters, discrete choice modelling; multinomial logit

1. INTRODUCTION

Automobiles have been the dominant transport mode since the twentieth century, and this trend has been reflected in the increase in vehicle ownership (Howard and Dai, 2014). The increasing rate of vehicle ownership has led to the reduction in vehicle occupancy rate and caused several problems such as congestion, environmental or economic issues (Sullivan and Fallon, 2003). Meanwhile, studies show that increase in trip sharing is likely to reduce vehicle travel. Even if a small percentage of single-occupant vehicle trips changes to two-person trips, significant changes could be seen in terms of reduction in vehicle travel (Greenblatt & Saxena 2015). Therefore, trip sharing is likely to address the current transport challenges such as excessive number of vehicles on roads, traffic congestion or air pollution. Trip sharing is expected to become more popular in the future and the current dominant modes of transport are likely to change (Burns, 2013).

In travel sharing studies, usually vehicle occupancy measures are used. Occupancy measuring is often associated with observing the number of travellers on a trip; therefore, there is not much information about the characteristics of travellers or the types of trips. A few studies have surveyed people and provided information about their trips and households' sociodemographic characteristics, while most of these studies have only considered the occupancy rate of vehicles (Sullivan & Fallon, 2003; Corpuz, 2005; Kockelman & Zhao, 2000).

Trip Sharing Studies

Kockelman and Zhao (2000) investigated the number of person per trip with different trip purposes in the US. They used a negative binomial regression model to estimate the impacts of using different trip purposes and vehicle types such as SUVs, Pickups and Minivans on the number of the person-trip per day. The results of the study show that the number of person-trip is likely to increase by 80% if trips take place on weekends with recreational purposes. Furthermore, they investigated vehicle occupancy rates using an ordered probit model. They found out that higher occupancy is expected when lower income households travel for shopping, eating outside or recreational purposes (Kockelman and Zhao, 2005). Another study conducted in New Zealand shows that the highest vehicle occupancy in Auckland, Wellington and Christchurch occurs in the evening (after 6:30 p.m.) and for trip with recreational or social purposes (Sullivan and Fallon, 2003). Furthermore, an Australian study shows that, on average, the lowest vehicle occupancy rate in Sydney occurs in the morning traffic hours on working days with the average vehicle occupancy rate of slightly higher than one person (Corpuz, 2005). Therefore, the results of this study show that the average household trip sharing varies based on trip purposes. For instance, on average, social and recreation trips with 1.35 occupants have the highest vehicle occupancy rate followed by personal business trips (1.28), shopping (1.24), education (1.16) trips and the lowest household vehicle occupancy rate is associated with work-related trips with 1.04 household members on a vehicle. It was shown that trips with higher occupancy number such as social and recreational purposes could have some impacts on reducing vehicle travel.

Most of the previous studies have only focused on vehicle occupancy; therefore, in this study, we focus on households' trip sharing undertaken by different transport modes. This study also aims at understanding the characteristics of individuals, households and trips that lead to an increase in trip sharing. The term 'household trip sharing' is used throughout this study to refer to the number of household members on a trip. Additionally, the difference between the effects of trip sharing and car sharing on vehicle travel should be noted. Trip sharing is likely to reduce vehicle travel but car sharing with one-person occupancy might increase vehicle travel due to the relocation of shared vehicles between different pick up points.

Car sharing

One of the innovative mobility solutions that is likely to influence travel experience is car sharing. Car sharing was developed to help reducing vehicle travel and ownership rate, and provide economical and personal advantages. Car sharing enables short-term on-demand car hiring on an hourly basis. During the past two decades, more than a million users worldwide have adopted car sharing and it is expected to become more popular in coming years (Dowling & Kent, 2015). Several car sharing organisations are currently operating in Australia (e.g., GoGet, DriveNow, GoCar, ZipCar) and therefore car sharing is expanding rapidly (Shaheen & Cohen, 2013; Zhou et al., 2017). Each shared vehicle likely replaces 7 to 9 private vehicles in Australia (Ramirez et al., 2007). Therefore, the current trip sharing patterns of car sharing users is considered in this study to understand the relationship between using car sharing and household trip sharing patterns.

Autonomous Vehicles

AVs are currently undergoing different road testings and it is expected that they will become widely available to the public by 2025 (Barcham, 2014). In this study, AVs are referred as fully automated vehicles that can perform all driving tasks without the need for a driver. AVs are also capable of transforming travel experience. If these vehicles become widely adopted, they are likely to make significant changes to the current transport system such as improving safety and traffic flow, and reducing the environmental impacts (Fagnant, 2014; Litman, 2014; Fagnant and Kara, 2013; Anderson *et al.*, 2014; Barcham, 2014). Assuming that AVs will provide the same travel experience, then changes in travel behaviour can be minor (Bierstedt et al., 2014). However, it is unlikely to happen as AVs are likely to transfer the current vehicle ownership decisions and consequently affect people's travel experience (Fagnant & Kockelman, 2013). It is plausible that these vehicles will act as shared household vehicles; therefore, one car might be able to address the travel needs of an entire household and eventually contribute to reducing the vehicle ownership rate (Schoettle & Sivak, 2015). In other words, AVs can address the mobility needs of one person and then serve mobility to other household members. Thus, exploring the current travel pattern of future AV adopters could shed light on their current trip characteristics.

Several prior studies have focused on people's attitudes toward adopting car sharing, AVs and shared autonomous vehicles (SAVs). These studies estimated the factors that can lead to the willingness or rejection of adopting these mobility solutions by analysing individuals' stated preferences and examining the potential demand for these solutions. Although these types of data provide insights into people's choices (Hensher, 1994; Adamowicz et al., 1997), they forecast the preferences that are built upon hypothetical choice situations (Marchau and Molin, 2002). In this study, we propose that understanding the current travel behaviour of car sharing and future AV adopters can provide information about trip sharing patterns future mobility solution adopters.

The objective of this study is to achieve a better understanding of households' current trip sharing decisions. A multinomial logit (MNL) model is proposed to analyse the data gathered form the five most populated cities in Australia including Sydney, Melbourne, Brisbane, Adelaide and Perth in 2016. The data contains comprehensive information about the trips household made during a day prior to data collection such as trip purposes, transport mode, number of householders who shared trips, number of vehicle households have access to, number of vehicles household owns, attitudes toward purchasing AVs, and households' sociodemographic characteristics. The contributions of this study include proposing a model to investigate the current household trip sharing patterns of car sharing users and future AV adopters. This study also argues that different transport modes and activities are likely to affect trip sharing patterns, while previously the private vehicle was considered as the main transport mode in trip sharing literature.

The remainder of the paper is organized as follows. Section 2 provides details about the research methodology, including information about the survey, dataset and the modelling analysis of the data. Section 3 presents the results and discussion of the estimation of the MNL model used for this dataset. Finally, Section 4 presents conclusion part of this study.

2. Methodology

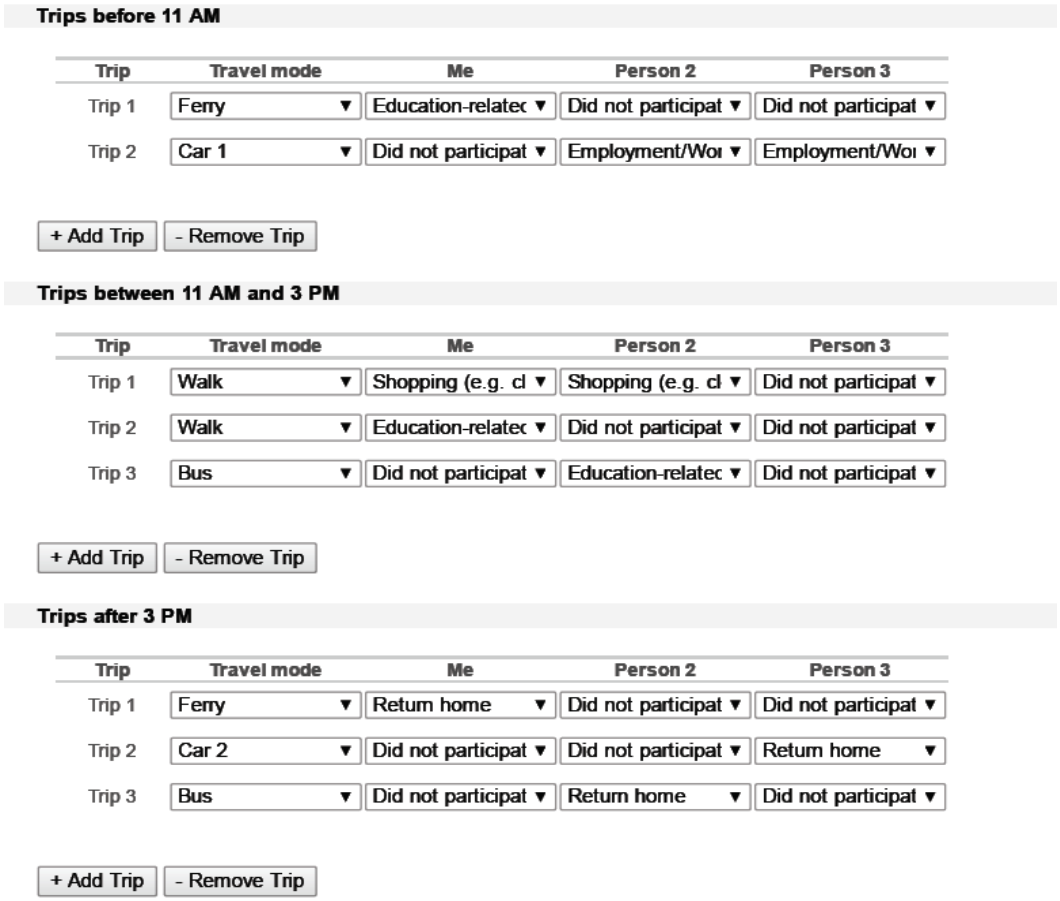
In order to have comprehensive information regarding households' trip sharing patterns, a survey was designed to capture various information regarding individuals and households' sociodemographic and trip characteristics. This section first discusses the design of the survey

and respondents' demographic statistics followed by the modelling approach to estimate the factors affecting household trip sharing.

2.1 Survey Data and Statistical Analysis

The survey was conducted in Australia in 2016. This survey gathered information about mobility and travel behaviour trends of 1,500 Australian households. The information contained in the survey includes households' socio-demographics, vehicle ownership (including two-wheelers), attitudes about AVs, trip characteristics. Respondents were asked to record the trips undertaken by their household on a day prior to data collection. The maximum number of daily trips undertaken by a person on day was restricted to 30 trips; maximum 10 trips before 11 AM, maximum 10 trips between 11 AM and 3 PM, and maximum 10 trips after 3 PM. According to a report by National Household Travel Survey (NHTS, 2011) in the US, the average daily number of trips per person is approximately between 3 to 5 trips; therefore, in this study in order to capture more information, higher number of trip could be reported by respondents. According to our results the average daily number of trips per person is 3 which is consistent with NHTS data; however, this number was as high as 10 trips for some respondents. Another restriction of this study includes the collection of the data from only the top five most populated urbanised areas in Australia. In addition to these restrictions, respondents were only allowed to add up to three household members in each trip (including him/herself). This is because according to Australian Bureau of Statistics (2015) average Australian household size is 2.6 people. Figure 1 shows a sample question of the trips that respondents and their household members made during a day before data collection.

Figure 1 an example of trip information question in the survey



A rich set of information about individuals, households, and commute trip characteristics was gathered from the survey. According to the data, not surprisingly most trips were made in Sydney (30.48%), since Sydney is the most populated city in Australia; this trend is followed by Melbourne with 27.68% and, Brisbane with 20.93. Regarding household size, households with 3 or more people undertook the highest number of the trips (more than 50% of trips). Households who have access to two cars made most of the trips with 36.91% in comparison to others. Additionally, respondents were asked if they would buy AVs in future, and some information about AVs was given in the information package of the survey (information video). Participants who stated that they would purchase AVs for their next vehicle purchase (potential AV buyers), made little less than half of the trips. Car sharing users made a small percentage of the trips (less than 10%). Those who said they are early technology adopter undertook 33.03% of the trips. Regarding the percentage of trips using different modes of transport, 69.94% of trips were made by private car, 1.74% by two-wheelers, 19.24% by public transport (including bus, train, tram, ferry and monorail), 8.31% by active transport (including cycling and walking) and only 0.77% of the trip were made by sharing services (including car sharing and hail).

In the survey, participants were also asked to provide information regarding trip purposes of at most three householders sharing a trip. Table 1 shows the statistics of average number of householders sharing trips with different purposes. Based on the statistics, the highest household trip sharing occurs when at least one of the travellers is travelling for educational purposes and the lowest when one person is travelling for work. Furthermore, the average number of vehicle occupancy is presented since most of trips were undertaken by personal vehicles. As there is not enough research on vehicle occupancy in Australia, we compared our sample to Corpuz (2005) study. The average number of vehicle occupancy in Sydney is shown in the fourth column of the table. The results are somewhat different with Corpuz (2005) findings since the results of this study shows higher rate of household vehicle occupancy. This could be because this study considered trips in an entire day during anytime of the week, while Corpuz (2005) focused on morning trip on weekdays. Overall, the highest number of trips are those with returning home purposes (1,626 trips) with the highest rate of single-person trips (1,017 trips). The lowest number of trips are those with recreational purposes with only 294 trips.

Table 1 the average number of householders sharing trips with different trips purposes and the number of trips made with different occupancy level

Trip purposes	Average number of householders on a trip			The number trips			
	Using different transport mode	Vehicle occupancy	**Vehicle occupancy in Sydney**	Single-person trips	2-person trips	Three-or-more-person trips	Total number of trips
Work-related	1.4	1.4	1.6	845	226	159	1,230
Educational	1.9	2.01	2.2	149	144	116	409
Recreational	1.7	1.67	1.9	145	90	59	294
Social	1.67	1.7	2.1	223	139	78	440
Shopping	1.62	1.63	1.9	332	185	100	617
Personal business	1.66	1.63	1.8	172	80	65	317
Return home	1.49	1.5	1.7	1,017	407	202	1,626

As mentioned earlier, respondents were asked if they would purchase AVs in future. Figure 2 illustrates the proportion of trip sharing undertaken by at least one household member who is willing to purchase AVs in future. In general, single-occupant trips have the highest rate of travellers who are willing to purchase AVs (59.65%). In total, potential AV buyers made smaller number of trips compared to non-AV buyers, while they had more shared trips compared to non-AV buyers. Furthermore, trips made by AV-buyers using different transport modes is shown in Figure 3. Not surprisingly, private cars have the highest percentage with 71%, since private cars have been the dominant mode of transport for decades (Howard & Dai 2014; Bureau of Transport Statistics, 2013). After private cars, public transport was the second most used mode undertaken by AV adopter households (20%) followed by active transport with 6.5% and two-wheelers (i.e. motorcycles, mopeds) with 1.75%. Shared transport modes such as car sharing and taxi were the least favoured transport modes among AV adopter households with less than 1% of usage.

Figure 2 the proportion of trip sharing of AV buyer households

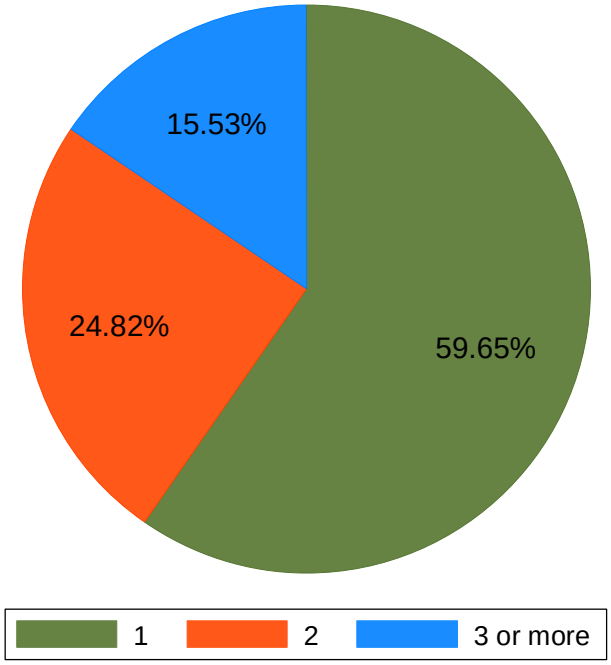
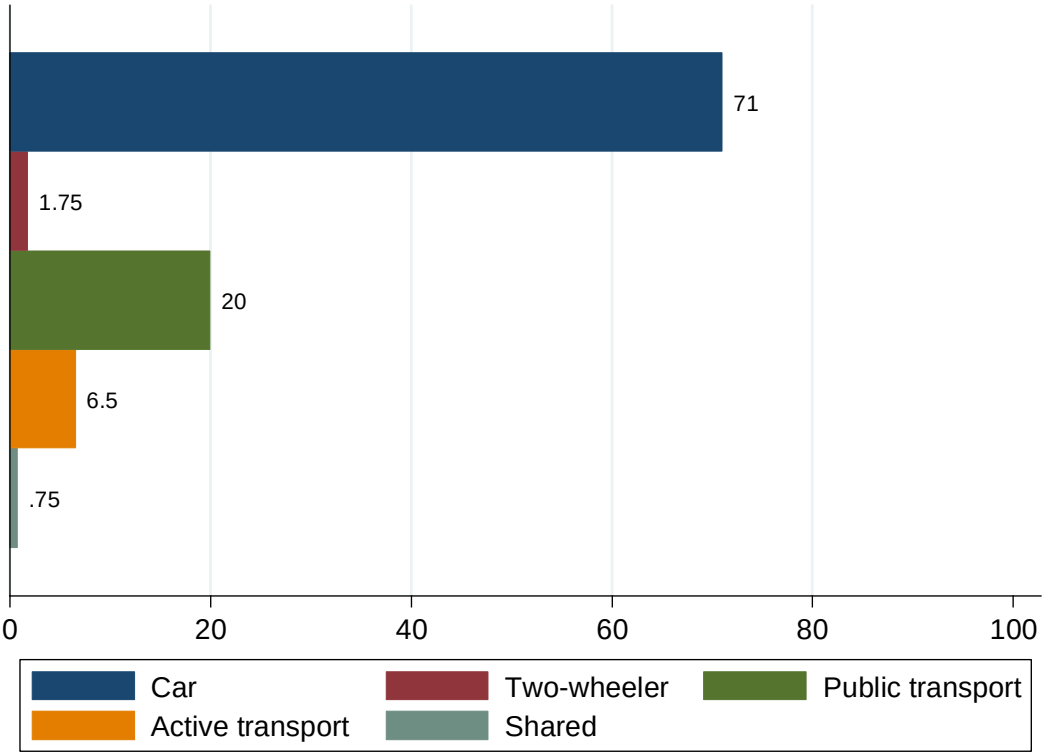
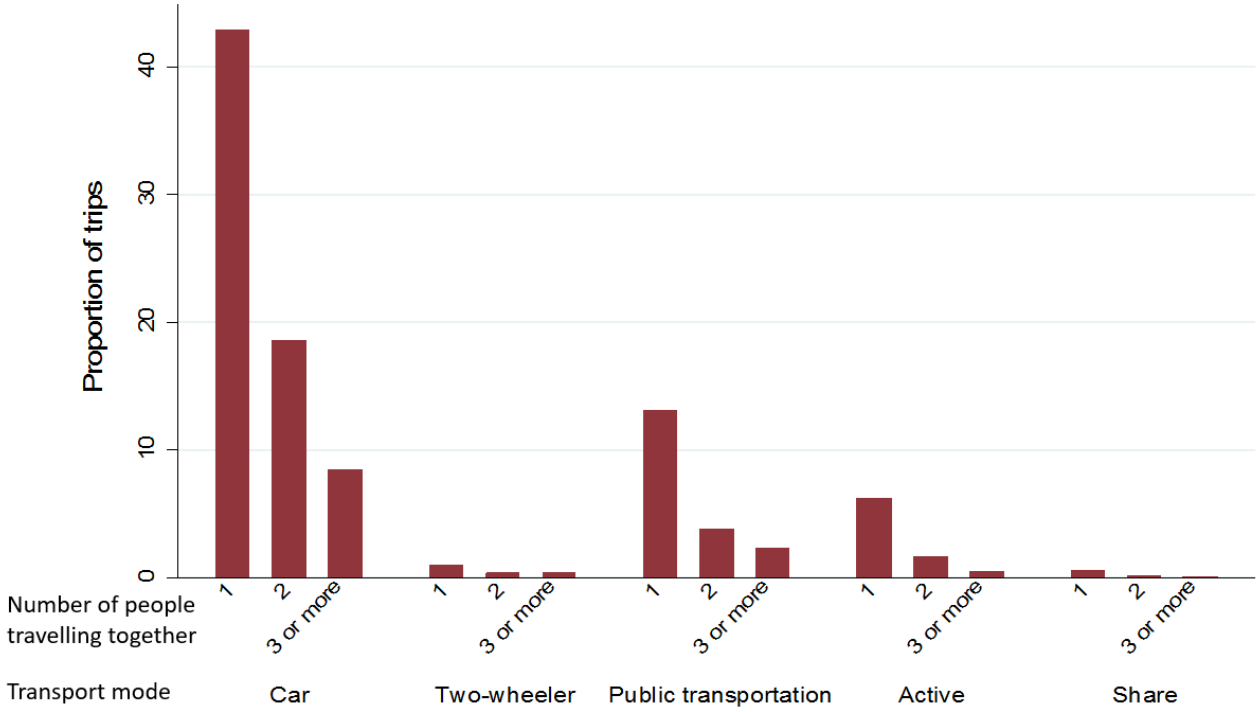


Figure 3 Proportion of trips made by AV buyers using different transport modes



The proportion of trips using different transport modes for the entire sample was also analysed. Similarly, the sampled respondents have chosen private cars as the main mode of transport, even for trips with higher occupancy rates. After private cars, active and public transport were the two highest used modes with more than 8% and 2% of trips shared by householders (See figure 4). Interestingly,17 trips were made with three or more participants using two-wheelers (such as motorcycles and mopeds).

Figure 4 the proportion of shared trips using different transport mode



2.2 Modelling Approach

The number of household members on a trip can be modelled by using discrete choice modelling. It is assumed that individuals share trips with different number of household members to maximise their utility. The utility is unobserved to the researcher and its function is separated to two parts; deterministic and unobserved portion (1). In this study, the choice of sharing a trip with different number of householders was estimated using a MNL model. Multinomial logit have been used frequently in the literature because of its convenient and ease of use (Bunch et al. 1993), however, this approach has its own limitations. Multinomial logit only allows for Independence of Irrelevant Alternatives (IIA) and cannot accommodate correlation among choices and error terms.

U_{in} represents the unobserved utility of i number of householders sharing trip n, V_{in} is deterministic portion of the utility and ε_{in} is the error term (or unobserved portion). The error terms in MNL models are independently and identically distributed (I.I.D) from a Gumbel type-2 distribution (Washington et al., 2010). Also in logit models, it is also assumed that the error terms are uncorrelated across the alternatives.

$$U_{in} = V_{in} + \varepsilon_{in} = \sum_{k=1}^{k} \beta_{ki} X_{in} + \varepsilon_{in} \quad (1)$$

X_{in} is a K-dimensional vector of attributes of trip sharing number i and β_k is k number of parameter estimated that weight each attribute X.

The probability of sharing a trip with other household members is as below:

$$P_{in} = \frac{EXP\,[\beta_i X_{in}]}{\sum EXP(\beta_k X_{kn})} \quad (2)$$

P_{in}, represents the probability that *i* person share a trip *n,* and β_i is again the parameter estimated.

After the calculation of the probability, the estimation of parameters (*β*s*)* can be found from the maximisation of the log-likelihood function (3):

$$LL(\beta) = \sum_{i=1}^{I} \sum_{n} \delta_{in} \ln P_{in} \quad (3)$$

where δ_{in} indicates whether *i* number of householders shared trip *n* and *β*s are those parameters that maximises the log-likelihood function. In this study, the modelling of households' trip sharing was carried out using PythonBiogeme (Bierlaire, 2016) and STATA.

3. Results and Discussion

Several models were estimated with different subsets of explanatory variables (*X*s) to search for a plausible, defensible, and 'best-fitting' model. The definitions of the explanatory and response variables are listed in Table 2.

The models aimed at explaining the relations between households' trip sharing pattern and their sociodemographic characteristics. Two different choice model formulations were tested:

1. Binomial logit model with 2 alternatives (single-person trips and more than one-person trips);
2. MNL model with 3 alternatives (single-person trips, two-person trips and three-or-more-person trips)

Table 2 Variable Definitions and Descriptions

Variables name	Definitions
Trip sharing	The number of householders sharing a trip; 1 for single-person trips; 2 for two-person trips; and 3 for three-or-more-person trips
University education	The highest university qualification attained by the decision maker*
Under 18 years old	1 if any of the travellers is under 18 years old, 0 otherwise
18-24 years old	1 if any of the travellers is between 18-24 years old, 0 otherwise
25-34 years old	1 if any of the travellers is between 25-34 years old, 0 otherwise
35-44 years old	1 if any of the travellers is between 35-44 years old, 0 otherwise
45-54 years old	1 if any of the travellers is between 45-54 years old, 0 otherwise
55-64 years old	1 if any of the travellers is between 55-64 years old, 0 otherwise
65-74 years old	1 if any of the travellers is between 65-74 years old, 0 otherwise
75 years old or older	1 if any of the travellers is 75 years old or older, 0 otherwise
High income	1 if households' income is higher than the average annual Australian income (AUD 78,000), 0 otherwise
Sydney	1 the household members live in Sydney, 0 otherwise
Melbourne	1 the household members live in Melbourne, 0 otherwise
Brisbane	1 the household members live in Brisbane, 0 otherwise
Adelaide	1 the household members live in Adelaide, 0 otherwise
Perth	1 the household members live in Perth, 0 otherwise
AV buyer	1 if any of the travellers is willing to purchase AVs in future, 0 otherwise
Active transport	1 if active transport was chosen as the mode of transport for the trip, 0 otherwise
Public transport	1 if public transport was chosen as the mode of transport for the trip, 0 otherwise
Early technology adopter	1 if any of the travellers are early technology adopters, 0 otherwise
Number of days using public transport	Number of days in a week that travellers use public transport
Total car	Total number of cars that households have access to (private and employer owned vehicles)
Access to train	1 if household members have access to train station, 0 otherwise
Car sharing user	1 if any of householders use car sharing service, 0 otherwise
Personal business trip	1 if any of the travellers have taken a personal business trip, 0 otherwise
Recreational trip	1 if any of the travellers have taken a recreational trip, 0 otherwise
Social trip	1 if any of the travellers have taken a social trip, 0 otherwise
Shopping trip	1 if any of the travellers have taken a shopping trip, 0 otherwise
Work-related trip	1 if any of the travellers have taken a work-related trip, 0 otherwise

*Decision maker is the person who completed the survey.

The results of the best fitting MNL model plausibly explain household level trip sharing patterns are shown in Table 3. Aggregating the number of occupants by two and more than two persons revealed an appealing specification. The final model includes three alternatives with 31 estimated parameters. The utility of a single-person trip is the baseline utility function. The constant parameters suggest that, if everything else were equal, it is unlikely for households to share simple trips (not trip chains). The magnitude of the parameter cannot be directly interpreted in MNL models; however, the signs of the parameters provide information of the likely effects of different variables on trip sharing.

As mentioned earlier, in this study, MNL was chosen to estimate the parameters. It was assumed that the model uses fixed parameters for all the observations. In addition to this restriction, some variables were joint as one; for instance, public transport variable includes bus, train, tram, monorail and ferry. This is because some specific modes like ferry were rarely used and in some cities, they were unavailable. Furthermore, the affordability of AVs is not the focus of this study, since it was assumed that AVs purchase price will not be much different from the price of vehicles from the current vehicle market. Additionally, this study suggest that trip sharing is affected by many factors at the same time. In regards to trip purpose, for instance, other household members were able to select different trip purposes while they shared a same transport mode; therefore, mode and trip purposes might both affect the sharing decisions. Regarding the selected trip that the householders shared together, it is assumed that trip was a simple trip and not chain.

According to the results, people with university education are more likely to share trips with at least another household member. The age variable indicates whether at least one of the travellers' age is within that range. For instance, if at least there is one person aged under 18 years participating in a trip, travellers tend to share trips with another, or more household members. These indicator variables, then, are not mutually exclusive. When there is at least one person between 18 and 24 years old, they are less likely to share their trips with another household, while interestingly, they would prefer to share their trips with two or more household members. This could be because this group of people are parents to young children and tend to travel with higher number of people. Another reason could be that people aged 18-24 are mostly university students, they travel alone to university but for other trips they travel with more household members. Expectedly, people over 75 years old are more likely to have higher occupancy trips as they probably prefer more people to accompany them to their destination.

High income households, households with annual income higher than AUD 78,000 (The Australian Bureau of Statistics, 2016), are less likely to share their trips with other householders, as they might own more personal vehicles and travel by car. This is in line with previous findings that high income households are more likely to participate in single-person trips (Srinivasan and Bhat, 2008). Not surprisingly, trips that were made by active or public transport or by those who have access to train are less likely to be shared by the household members. This seems reasonable given that these people may travel with different trip purposes and they can have the option to choose different routes, timetable and services in their own preferred ways. Furthermore, people who travelled by public transport are more likely to enjoy travelling alone or independently (Clifton, 2003) and they like to read and relax during their trip; therefore, they prefer to travel alone (NSW Bureau of Transport Statistics, 2013). Regarding the city, the findings show that, compared to travellers from Sydney, those who come from all other cities (Melbourne, Brisbane, Adelaide and Perth) are less likely to share trips with household members.

Those who report to be early technology adopters are more likely to share trips with two or more householders. Another noteworthy variable of this study is the households who would purchase AVs in future; these people are more likely to have higher trip sharing (trips involving three or more people). This is interesting since the parameters for both AV buyers and early technology adopters were not significant in the case of two-person trips. This could mean that those who are more environmentally aware and wish to travel in groups to reduce vehicle emissions. Additionally, if we consider AVs as the future shared household vehicles, then vehicles ownership could be reduced and shared trips could increase in future (Schoettle and Sivak, 2015).

Interestingly, car sharing users are less likely to share their trips with other householders. These findings conflict with other studies that suggest car sharing users tend to travel with others (Cervero, Golub and Nee, 2006). These contrary findings could be the result of estimating car sharing users travel decisions even though they use other transport modes, while previous studies estimated vehicle occupancy of car sharing vehicles.

Those who use public transport more often tend to share their trips with others. This could be because they do not mind trip sharing in general. Not surprisingly, those households who have access to more cars are less likely to share trips with others. Finally, in almost all trip purposes including recreational, social, shopping, educational and personal business, householders are more likely to share their trips. However, those who undertake work-related trips are less likely to share trips with other household members.

Table 3 Estimated MNL Model Parameters

Log-likelihood = -3511.834 AIC = 7109.668	Two-person trips		Three-or-more-person trips	
	β	t-test	β	t-test
Constant	-1.12	-3.62 **	-3.33	-8.79 **
Education	0.222	13.26 **	0.148	4.32 **
Under 18 years old	0.338	3.79 **	2.29	17.64 **
18-24 years old	-0.288	-2.91 **	0.979	6.87 **
25-34 years old	0.165	1.94 **	0.868	6.81 **
35-44 years old	-	-	0.647	4.99 **
45-54 years old	0.186	2.16 **	0.400	2.90 **
55-64 years old	-	-	0.545	3.14 **
65-74 years old	0.392	2.50 **	-	-
75 years old or older	-	-	1.27	3.25 **
High income	-0.212	-2.78 **	-	-
Active transport (cycle and walk)	-0.752	-5.06 **	-0.910	-3.69 **
Public transport	-0.569	-5.17 **	-0.340	-2.36 **
City				
Sydney (base)	-	-	-	-
Melbourne	-	-	-0.637	-4.65 **
Brisbane	-	-	-0.511	-3.36 **
Adelaide	-	-	-0.442	-2.59 **
Perth	-	-	-0.724	-3.23 **
Early technology adopter	-	-	0.298	2.67**
AV buyer	-		0.230	2.18 **
Number of days using public transport	-	-	0.0568	3.37 **
Access to train	-	-	-0.231	-1.94 **
Total car	-0.123	-3.37 **	-	-
Car sharing user	-0.242	-1.72 *	-0.750	-4.74 **
Recreational trip	0.669	4.48 **	1.27	6.93 **
Social trip	0.765	6.17 **	1.49	8.92 **
Shopping trip	0.627	5.81 **	1.30	8.54 **
Educational trip	1.13	8.49 **	1.35	8.43 **
Work-related trip	-0.344	-3.74 **	-	-
Personal business trip	0.363	2.44 **	1.04	6.34 **

** Significant at $p \leq 0.05$.

* Significant at $p \leq 0.1$.

4. Conclusion

Using data from a recent Australian household survey, this study investigated different characteristics of household-level trip making to understand their impacts on household trip sharing decisions. Households with older members and higher education levels who use public transport more often have the propensity to travel with other household members. Similarly, potential AV buyers or early technology adopters tend to share tips with their households. It was also determined that high income households from cities like Melbourne, Brisbane, Adelaide, and Perth, compared to Sydney, are less likely to make high occupancy trips. Additionally, households with access to more vehicles and are car sharing users are more likely to travel alone. Household members who are likely to purchase AVs in the future tend to travel more with personal cars and have higher occupancy trip rates. Therefore, with the future availability of AVs, average occupancy rates of these vehicles could be higher on average than for non-automated vehicles.

The findings can be useful for future transport planning and can offer guidance to policy makers on understanding the existing travel trends of car sharing and AVs adopters and developing effective policies to influence or be prepared for such trends. It is important to emphasise that the evidence does not suggest that buying an AV will lead to an increased tendency to increase average occupancy, but rather, that the self-reported early adopters of AVs tend to travel already with above average occupancies and are self-selected. The question of whether the AV itself will have a follow-on impact on occupancy is an interesting and important question for further study.

References:

Anderson, J.M., Nidhi, K., Stanley, K.D., Sorensen, P., Samaras, C. and Oluwatola, O.A., 2014. *Autonomous vehicle technology: A guide for policymakers*. Rand Corporation.

Barcham, R. (2014) ‘Climate and Energy Impacts of Automated Vehicles’, pp. 1–30.

Bierlaire, M., 2016. *PythonBiogeme: a short introduction* (No. EPFL-REPORT-221362).

Bierstedt, J., Gooze, A., Gray, C., Peterman, J., Raykin, L. and Walters, J., 2014. Effects of next-generation vehicles on travel demand and highway capacity. *FP Think Working Group*, pp.10-11.

Bureau of Transport Statistics (2013) ‘Public Transport Users in Sydney’, (january), pp. 1–4.

Burns, L.D., 2013. Sustainable mobility: a vision of our transport future. *Nature*, *497*(7448), pp.181-182.

Cervero, R., Golub, A. and Nee, B., 2006. *San Francisco City CarShare: Longer-term travel-demand and car ownership impacts*(No. 2006, 07). Working Paper, Institute of Urban and Regional Development.

Clifton, K., 2003. Independent mobility among teenagers: exploration of travel to after-school activities. *Transportation Research Record: Journal of the Transportation Research Board*, (1854), pp.74-80.

Corpuz, G., 2006, September. Analysis of peak hour travel using the Sydney household travel survey data. In *Proceedings from the 29th Australasian Transport Research Forum*.

Dowling, R. and Kent, J., 2015. Practice and public–private partnerships in sustainable transport governance: The case of car sharing in Sydney, Australia. *Transport Policy*, *40*, pp.58-64.

Fagnant, D.J. and Kockelman, K., 2014. Preparing a nation for autonomous vehicles: 1 opportunities, barriers and policy recommendations for 2 capitalizing on self-driven vehicles 3. *Transp. Res*, *20*.

Howard, D. and Dai, D., 2014. Public perceptions of self-driving cars: The case of Berkeley, California. In *Transportation Research Board 93rd Annual Meeting* (Vol. 14, No. 4502).

Kockelman, K.M. and Zhao, Y., 2000. Behavioral distinctions: The use of light-duty trucks and passenger cars. *Journal of Transportation and Statistics*, *3*(3), pp.47-60.

Litman, T., 2014. Autonomous vehicle implementation predictions. *Victoria Transport Policy Institute*, *28*.

NHTS, 2011. *Summary of Travel Trends: 2009 National Household Travel Survey*

NSW Bureau of Transport Statistics (2013) *2011 / 12 Household Travel Survey Summary Report 2013 Release*.

Ramirez, M., Tonkinwise, C. and Nawangpalupi, C. (2007) 'Multiplier and Transfer Effects of Car Sharing in Australia', *SCORE! Sustainable Consumption Research Exchange Expert Workshop and Conference, 2007, November*.

Schoettle, B. and Sivak, M., 2015. Potential impact of self-driving vehicles on household vehicle demand and usage.

Shaheen, S.A. and Cohen, A.P., 2013. Carsharing and personal vehicle services: worldwide market developments and emerging trends. *International Journal of Sustainable Transportation*, *7*(1), pp.5-34.

Sullivan, C. and O'Fallon, C., 2003, October. Vehicle occupancy in New Zealand's three largest urban areas. In *26th Australasian Transport Research Forum, Wellington* (pp. 1-3).

The Australian Bureau of Statistics (2016) *Average Weekly Earnings, Australia, Nov 2016*.

Australian Bureau of Statistics, 2015. *Household and Family Projections, Australia, 2011 to 2036.* Available: at: http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/3236.0Main%20Features42011%20to%202036

Washington, S.P., Karlaftis, M.G. and Mannering, F., 2010. *Statistical and econometric methods for transportation data analysis*. CRC press.

Zhou, F., Zheng, Z., Whitehead, J., Perrons, R., Page, L. and Washington, S., 2017. Projected prevalence of car-sharing in four Asian-Pacific countries in 2030: What the experts think. *Transportation Research Part C: Emerging Technologies*, *84*, pp.158-177.