The Role of Residential Choice on the Travel Behavior of Young Adults

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Abstract

Several studies have shown that the travel behavior of young adults in the United States in the past two decades differed from that of prior generations. On average, recent young adults drove fewer miles, owned fewer vehicles and made use of public transit more often. A higher share of young adults also chose to live in cities. This study examines the relationship between the location decision of young adults and their travel behavior. We examine how being a young adult and other socioeconomic variables are associated with residential location decisions, and how these in turn affect vehicle ownership, mode choice and travel distance. Our analysis uses household travel survey data from the Seattle regions collected in 2006 and 2017 and employs a recursive structural equation model to examine these questions. We find that young adult households were more likely to live closer to the city center and to have fewer vehicles than older ones. Fewer young adults also chose to own vehicles in 2017 than in 2006. While young adults made more use of non-automobile modes and had fewer person miles travelled, we find that these effects were more due to their residential location and vehicle ownership decisions than due to direct preferences about mode or distance travelled. These findings suggest that significant changes would be expected in the mode use and miles travelled among young adults if their residential location or vehicle ownership preferences change significantly due to life cycle or other factors.

Keywords: Young adults, Travel behavior, Residential location choice, Vehicle Ownership, Mode choice, and Person miles traveled

1. Introduction

Over the past two decades, many studies have shown that young adults in the United States on average drove less, owned fewer cars, and delayed acquiring a driver's license when compared to prior generations. More young adults also used multiple modes, including public transit and bicycles, at a higher rate than similarly aged cohorts before them (Blumenberg et al. 2015; Klein and Smart 2017; Chatterjee et al. 2018; McDonald 2015; Delbosc and Currie 2013; Kuhnimhof et al. 2012; Oakil, Manting, and Nijland 2016; Polzin, Chu, and Godfrey 2014). These travel behavior changes occurred primarily among young adults and not among older age groups in the same period (Polzin, Chu, and Godfrey 2014). At the same time, a higher share of young adults was also living in cities as compared to older adults and similarly aged prior cohorts (Blumenberg et al. 2015; Lee 2018; Moos 2016; Myers 2016). A higher number and higher proportion of young adults was also living in central cities in the early and mid 2010s than in the early 2000s (Lee 2018; Moos 2016; Cortright 2014; Walter-Joseph 2015). Studies also show that young

adults were more likely to choose residential locations that have better public transit or high accessibility (Pendall 2012; Deka 2018) as well as areas with more job opportunities or higher densities (Deka 2018; Lee 2018).

Age can influence residential and travel choices for a variety of reasons. Young adults often do not have the constraints imposed by larger families and children, and this may allow choices that are different from their older counterparts. Their economic position may also be weaker, and as a result, their choices may be different from older and more economically established adults. Even after controlling for these variables, young adults' choices as a group may be different from older ones in the same period because their tastes and attitudes have developed under different circumstances. These differences maybe reflected in residential choices and travel decisions.

The residential and travel preferences of young adults may also influence one another. It is well established that neighborhood characteristics such as high density, proximity to public transit, land use diversity, and street network design influence mode choice particularly for public transit and walking (Cervero and Kockelman 1997; Ewing and Cervero 2010; Voulgaris et al. 2017). Hence, it is possible that some of the observed travel behavior among young adults arises from the built environment of their chosen residence. On the other hand, the transportation attitudes of young adults may lead them to choose residential areas that align with their preferences. A broad range of research has looked at the possibility of residential self-selection being the reason for the observed travel behavior of people as opposed to travel behavior being driven by the built environment. Reviews by Cao, Mokhtarian, and Handy (2009) and Mokhtarian and Herick (2016) find that both attitudinal factors and the built environment contribute to travel behavior.

A key question for our study is to what extent the travel behavior of young adults arises from their age group membership, and to what extent it arises from their residential location decisions. We also examine how these preferences have changed from 2006 to 2017, the two time periods when the data for this study were collected. We focus on four decisions: the residential location (as measured by distance from the central business district), vehicle ownership, mode choice, and distance traveled. At one extreme, we can imagine that age-group membership only influences residential choice but does not directly affect the vehicle ownership and travel variables. Because location affects travel behavior, age-group may still have indirect downstream effects on auto ownership, mode choice and distance travelled. Another possibility is that auto-ownership is not directly impacted by age-group membership, but residential choice, mode choice and distance travelled are. Location, auto-ownership and other decisions could also be principally influenced by other variables such as economic conditions or education but not by age-group. What is clear from the literature is that both residential choices and travel decisions of young adults have

changed. In this study, we examine how age group and time period influence these four decisions both directly and indirectly while also controlling for a variety of personal and household variables.

To undertake this analysis, we employ a recursive structural equation model (a path model with only observed variables) whose basic structure is shown in the path diagram in Figure 1. Three sets of decisions are analyzed—residential choice, automobile ownership and trip decisions about mode and distance traveled. We consider residential location to be a long-term decision and vehicle ownership a medium-term decision; mode choice and distance traveled are considered short-term decisions (Levinson and Krizek 2007). The model is structured with this decision time horizon in mind, with longer term decisions influencing shorter term ones. Residential location decisions are thus assumed to have direct influence on vehicle ownership, mode choice and travel distance. Vehicle ownership is expected to have direct impacts on mode choice and travel distance while also mediating the influence of residential decisions on mode and distance. This setup allows us to disentangle direct impacts from indirect ones and separately examine contributions to mode choice and distance travelled.

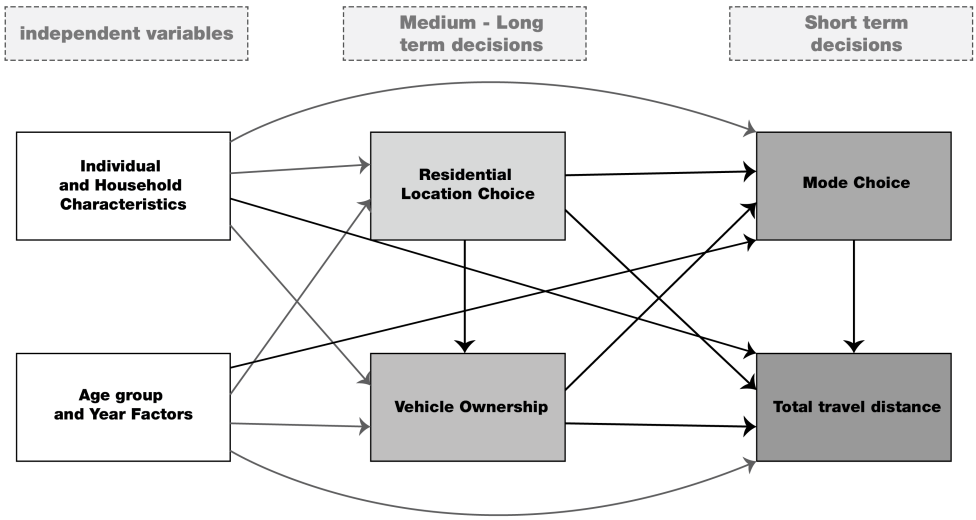

Figure 1: The proposed model structure

We consider residential location choice and vehicle ownership to be decisions made by the household. We assume mode choice and distance traveled are individual decisions. Our analysis accommodates these different decision making units by controlling for household level variables when residential choice and vehicle ownership are concerned and by con-

trolling for individual level variables for mode and distance traveled decisions. We discuss these details in section 3.

The model we estimate allows us to answer several questions, primary among those are: (1) How do residential location, mode ownership, mode choice and travel distance of young adults compare to older ones, and were there changes in the behavior of young adults between 2006 and 2017? (2) How do the direct impacts of age group membership on travel choices compare with the impacts of endogenous variables such as location choice and vehicle ownership? (3) Among young adults, which socio-demographic variables are strong markers for a preference to live closer to the city center and to adopt more sustainable travel choices, and (4) what do these findings suggest about the future choices of young adults? Our findings confirm earlier research which found that young adults lived closer to the city center, owned fewer cars, used non-automobile modes more and had lower person miles travelled. Between 2006 and 2017, the largest difference among young adults is the further decline in vehicle ownership. Second, the impacts of residential choice and auto-ownership on travel choices are larger than that of age group membership. Third, income and education have large impacts on residential and auto-ownership decisions. The impact of both variables on location choice exceeds that of age group membership. Finally, because residential location has strong influences on auto ownership, non-auto mode use and PMT, we think the gains in multi-modality and reductions in PMT among young adults can be lost if life cycle or other factors change the prevailing residential preference among young adults.

2. Background

Residential location choice and travel behavior can be different on account of age and cohort membership. Most cross-sectional studies that control for age can assess how the choices of young adults compare with older adults in the same period. Some researchers also explore cohort differences in such a setting where the cohorts are at different ages. In general, what these studies show is that young adults have shown a higher inclination to live in central cities, a preference for denser areas, rental housing, higher levels of use of non-automobile modes and lower distance traveled than their older counterparts (Kim, Orazem, and Otto 2001; Guo and Bhat 2007; Tu and Goldfinch 1996; Jun and Morrow-Jones 2011; Taylor et al. 2013; Lin and Long 2008; Circella et al. 2017).

Researchers have also looked at how the choices of young adults has shifted as a group by comparing the behavior of different cohorts at comparable ages (e.g., Millennials vs. Generation X when both cohorts were in some fixed age range). Some studies demon-

strate a cohort effect for Millennials although the magnitude is different by studies. The studies also find that Millennials show lower vehicle miles traveled (VMT) and personal miles traveled (PMT), lower number of vehicle trips, fewer vehicle ownership, and higher percentage of living in dense and public transit-friendly neighborhoods than the same-aged cohorts in prior generations (Wang 2019; Silva et al. 2019; Klein and Smart 2017; Blumenberg et al. 2012; Polzin, Chu, and Godfrey 2014; McDonald 2015).

Specifically, studies analyzing differences between the 1995, 2001, and 2009 NHTS (National Household Travel Survey) show that the vehicle miles traveled (VMT) and person miles traveled (PMT) of young adults declined sharply in 2009 as compared to 2001 and when compared to other age groups (Polzin, Chu, and Godfrey 2014; Blumenberg et al. 2012; McDonald 2015). VMT and PMT for young adults aged between 20 and 39 decreased by about 20% while that for other age groups stayed flat or only slightly decreased in 2009. Wang (2019) and Silva et al. (2019) compares personal VMT and the number of trips between Millennials and Generation X, and shows that Millennials had lower VMT and made fewer car trips than Generation X. Studies including (Kuhnimhof et al. 2012; Delbosc and Currie 2013; Taylor et al. 2013; Thompson and Weissmann 2012) show that young adults are less likely to acquire a driver's license and drive a car in 2009 than 2001.

Several studies analyzing the background of young adults point to the economic downturn and different life cycle choices (e.g. delaying family formation) as drivers of the travel behavior shift among young adults. The deterioration of socioeconomic conditions caused by the economic recession of 2007-2009 seriously influenced travel behavior changes (Blumenberg et al. 2012; McDonald 2015; Taylor et al. 2013; Raimond and Milthorpe 2010; Hedman 2011). Blumenberg et al. (2012), for example, argue that the economic downturn significantly affected young adults, many of whom had a relatively weaker economic base. After the recession, unemployment rates increased among all age groups but the rate among young adults was about twice higher than others in 2010 (Chatterjee et al. 2018; Demos and Young Invincibles 2011; Federal Interagency Forum on Child and Family Statistic 2014). These studies argued that the increase in unemployment rate and, consequently, the decrease in disposable income of young adults became a direct factor that reduced their travel needs, frequencies and distances travelled.

Several research also shows that as the unemployment rate for young adults increased, many started to enroll in higher education (Furstenberg Jr 2010; The Council of Economic Advisers 2014; Demos and Young Invincibles 2011). Furstenberg Jr (2010) states that travel demand and distance of young adults decreased because they stayed in school longer and delayed starting economic activity. The deterioration of economic circumstances and the longer education period led to the postponement of family formation. The delaying

of marriage and childbirth influenced travel needs and frequency of young adults as compared to similar age groups in prior generations (Heath 2008; Furstenberg Jr 2010; The Council of Economic Advisers 2014; Demos and Young Invincibles 2011; Pendall 2012). In addition, higher educational attainment led to large increases in student loan debt which further aggravated their weak economic base and delayed their economic independence as well as decisions to live alone or own a car after graduation (The Council of Economic Advisers 2014; Demos and Young Invincibles 2011; Federal Interagency Forum on Child and Family Statistic 2014).

In addition to travel behavior, another major change among young adults has been their residential location choice. Several studies show increasing numbers of young adults and Millennials were starting to live in cities through the 2000s (Moos 2016; Walter-Joseph 2015; Blumenberg et al. 2015; Cortright 2014). Moos (2016) finds a stronger association between density and young cohorts in 2006 while the same association was largely absent when prior data from 1981 was used in three Canadian cities. Cortright (2014) finds that the share of young adults, particularly those who are highly educated, living in central neighborhoods within 3 miles from urban cores increased between 2000 and 2012 . Lee (2018) also shows that Millennials were more likely to live in urban core areas within 3 miles from CBD (Central Business District) and in 3-10 mile areas, than prior generations. Using first time home buyer data, Raymond, Dill, and Lee (2018) find that Millennials had a higher chance of buying near city centers than Generation X-ers. In contrast, Wang, Lee, and Greenlee (2021) only find limited differences between Millenials and older cohorts in residential location choice. They find Millennials who are single, and those that are married and have no children, had a positive preference for places with higher job accessibility by transit. Single Millennials with no children also preferred high amenity areas. However, they find no differences in tastes for distance to CBD or compactness of a neighborhood that sets Millennials apart from other generations.

More recently, however, some studies have argued that the rate of car ownership of young adults is increasing as their economic situation improves and as they are aging (Klein and Smart 2017; Delbosc and Ralph 2017). Residential densities of the home location of young adults declined and their car ownership rate increased as Millennials aged between 1999 and 2013 (Klein and Smart 2017). As their economic and living conditions improved in the mid 2010s, more of them moved to the suburbs, owned more cars, and drove longer distances (Delbosc and Ralph 2017). Delbosc et al. (2019) emphasizes that the travel behavior of young adults can be different depending on local contexts such as by cities or countries. The recent work by Lee (2021) shows that both the youthification of the city and the suburbanization of older young adults are happening simultaneously. Younger people continue to live in cities in higher numbers while the older-young adults show a preference

to move to suburban locations.

Much research has shown that the residential and travel behavior decisions are linked. The tendency among young adults to choose central cities at a higher rate emerged at a similar time as their travel behavior changes. In what follows, we investigate the interrelationship between these two major phenomena among young adults.

3. Data and Approach

This study uses the 2006 and 2017 Household Travel Surveys collected by the Puget Sound Regional Council, the planning agency for the central Puget Sound region centered on Seattle and encompassing the coastal area of the Northwest in Washington state. The travel surveys collected a one day travel diary and socio-economic information of the surveyed households and individual household members. The 2006 Household Travel Survey had data on 10,516 persons from 4,746 households and their 87,600 trips. The 2017 Household Travel Survey has a total of 6,254 individuals from 3,285 households and their 52,492 trips. The samples come from King, Kitsap, Pierce, and Snohomish Counties.

For this analysis, we divide the samples in both surveys into two groups by age: *young adults* who were aged between 18 and 34 at the time of the survey, and *older adults* aged 35 or over at the time of the survey. Because age in the survey was collected as a categorical variable in 10 year increments, there is some generational overlap in these age ranges at the two survey points. Those who were in the range of 29-34 in 2017 would have been in the range of 18-23 in 2006. Thus a portion of 2017 young adult group were also young adults in 2006. Because of this overlap, our analysis is not able to examine generational differences. Instead, we examine if the behavior of young adults in 2006 collectively is different from that of young adults in 2017 (the presence of a period effect), whether there are age group membership differences relative to older adults, and if there are any period by age-group interactions.

We extracted location and three travel variables —vehicle ownership, mode choice, and person miles travelled (PMT)—and the individual and household information from both surveys. Residential location is expressed as distance from downtown Seattle. Distance is chosen for its simplicity and its ability to directly capture proximity to the core of the city.[1] Other studies also use distance in their analysis of the residential location of young adults (Lee 2018, 2021; Raymond, Dill, and Lee 2018; Cortright 2014; Wang, Lee, and Greenlee

1. We also considered the use of population density in lieu of distance as the residential choice variable. The two variables have a correlation of -0.532 in our data. While the models estimated were largely similar to the ones with distance, the overall goodness of fit of the models fell.

2021). We compute distance from Seattle's city hall to the centroid of the census tract of the respondent. Vehicle ownership is measured by the number of vehicles in a household. Mode choice (or more appropriately mode use) is measured on a continuous scale as the proportion of total distance traveled by non-automobile modes over all reported trips during the survey period. This covers the proportion of distances traveled by public transit, walking and bicycling as a primary mode for each trip. Finally, PMT is also computed to capture total traveled miles by each individual on the assigned survey day.

We distinguish between decisions made at the household level and those made at the individual level. Residential location and vehicle ownership decisions are treated as household level decisions. Independent variables linked to these choices are those attributes that correspond to the head of household (*householder* hereafter). The householder is selected in this study as the oldest full time working adult in the household. This person is used to determine the household's age group and education level. We assume that travel decisions are made at the individual level. These decisions are therefore tied to the individual reporting mode and distance traveled. For instance, in a household with three adults composed of a householder aged 34 (a young adult), a spouse aged 32 (a young adult), and a retired parent aged 70, the household level decisions are linked to the householder but travel decisions are linked to the individuals. The analysis uses the weights that were provided in the two household travel surveys. However, since the weights for the two periods are reported on different scales, these are re-scaled so the weights in each period sum to 100.

The analysis focuses on individuals who traveled at least once for home-based work or work related trip during the survey period. In preparing the data, we removed survey participants who had no work or work related trip information and those with missing information on modeled individual or household characteristics. The final data had 345 and 865 young adult households in 2006 and 2017, respectively, and 2,526 and 1,220 older adult households ($\geq$ 35 years) in 2006 and 2017, respectively. At the individual level, this translates to 735 and 1,291 young adults in 2006 and 2017 respectively, and 3,352 and 1,477 individuals who are older than 35 in 2006 and 2017 respectively. Table 1 provides a summary of the descriptive statistics for the data.

In both 2006 and 2017, young adults had smaller household size and owned fewer vehicles than the older age group. In both surveys, about half of households in the older age group reported having more than one working household member. In the young adult group, the percentage with more than one person working increased from 40% in 2006 to 70% in 2017. In general, the 2017 respondents reported higher average incomes than their 2006 counterparts (CPI adjusted to 2017$). The percentage of households with children under 5 years of age fell for both the older and younger groups in 2017 while the percentage with children aged 5-15 was similar between the two survey years. Consistent with the

Table 1: Summary of the Puget Sound household travel surveys in 2006 and 2017 by age group used in this analysis (weighted)

	2006		2017	
	Young adults	Older adults	Young adults	Older adults
The number of households (by householder's age)	345	2,526	865	1,220
The number of individuals (by individual's age)	735	3,352	1,291	1,477
Household related charactersitcs				
Percent of households living in Seattle	27.09	17.09	30.12	15.68
Average distance to downtown Seattle (miles)	16.27	17.33	15.52	18.22
Standard deviation of distance to downtown Seattle*	11.28	10.20	10.17	10.56
Number of vehicles	1.60	2.15	1.59	2.01
Standard deviation of number of vehicles*	0.88	1.13	0.84	1.06
Average of number of household members	2.26	2.67	2.38	2.60
Percent of single adult households	31.99	24.39	20.27	28.28
Average number of workers in a household	1.39	1.59	1.83	1.62
Percent with more than one worker	39.84	50.89	68.56	51.55
Percent with children under age 5	32.74	13.95	21.91	7.64
Percent with children aged 5 - 15	18.43	48.42	18.29	47.13
Percent with children aged 16 - 17	0.67	10.85	0.05	11.56
Percent with bachelor's degree or higher (householder)	62.56	58.15	67.62	67.97
Average household income ($1,000s, 2017 dollars)	65.81	94.99	90.81	100.12
Individual related characteristics				
Percent male	50.78	52.28	53.92	49.16
Percent with bachelor's degree or higher	50.17	52.33	53.64	63.55
Total number of trips	3.93	4.16	3.61	4.26
Person miles travelled - PMT (miles)	32.34	33.62	26.07	32.86
Standard deviation of person miles travelled*	22.22	23.21	19.32	21.23
Percent of PMT by non-automobile modes	18.48	11.93	27.73	12.80
Standard deviation of PMT by non-automobile modes*	35.84	30.11	41.38	31.51

**Standard deviations provided for endogenous model variables*

literature on young adults, more young adult households in 2017 lived in the city of Seattle as compared to young adults in 2006 (30.1% vs 27.1%). The average distance of young adult residences to downtown Seattle was shorter in 2017. Among older households, the percent living in the city showed a small dropped in 2017 and the average distance to downtown increased.

For the individual traveler data, the sample is roughly evenly split by sex. The 2017 respondents reported higher levels of education than their 2006 counterparts. These numbers are similar to the 2013-2017 5-year American Community Survey (ACS) estimates for King County and the City of Seattle, and slightly higher than other Counties. The data also shows higher number of trips for the older groups than the young ones in both periods. Average number of trips have only changed slightly for both groups over the period. More noticeable changes are observed in the percentage of miles traveled by non-automobile modes and PMT for young adults. The percentage of miles traveled by non-automobile modes for young adults rose from 18.5% to 27.7% whereas the non-automobile percentage rose only slightly for the older age group. A marked difference is also observed in miles traveled among young adults which fell from 32.3 miles in 2006 to 26.1 miles in 2017. Young adults made on average the same number of trips in 2006 as in 2017, but in 2017 a higher proportion of the distance was traveled by non-automobile modes and their average miles traveled fell.

4. Models and Results

As mentioned in the introduction, we employ a recursive structural equation model to examine the relationship between age-group and socio-economic variables, and among four key decisions: residential location choice, vehicle ownership, mode choice, and travel distance. We pay special attention to the role of residential location choice on travel behavior both directly and indirectly. We also examine the impact of being a young adult on location and travel choices by adding a dummy variable for those who are 18-35 years of age in each survey year. We account for choice differences between periods using a dummy variable for the survey year and its interaction with the age-group variable. The path diagram for the model is shown in Figure 2.

The basic logic of the model is as follows: household characteristics inform residential location choice. Variables such as number of adults, number of workers, number of children, income, and the householder's age are expected to influence the household's residential location choice. Since we are interested in proximity to the city center, we primarily focus on how far the chosen residence is from downtown Seattle (*RD*, residential distance). The distance is also closely related to density and transit accessibility. The household variables and the residential location decision are then expected to influence the vehicle ownership decision (V). While vehicle ownership decisions may predate residential choice, adjustments can be made relatively easily if there is a need for change conditional on the residential location's attributes (e.g., density, level of transit service, accessibility, etc.). For example, while a household may have two vehicles when they made

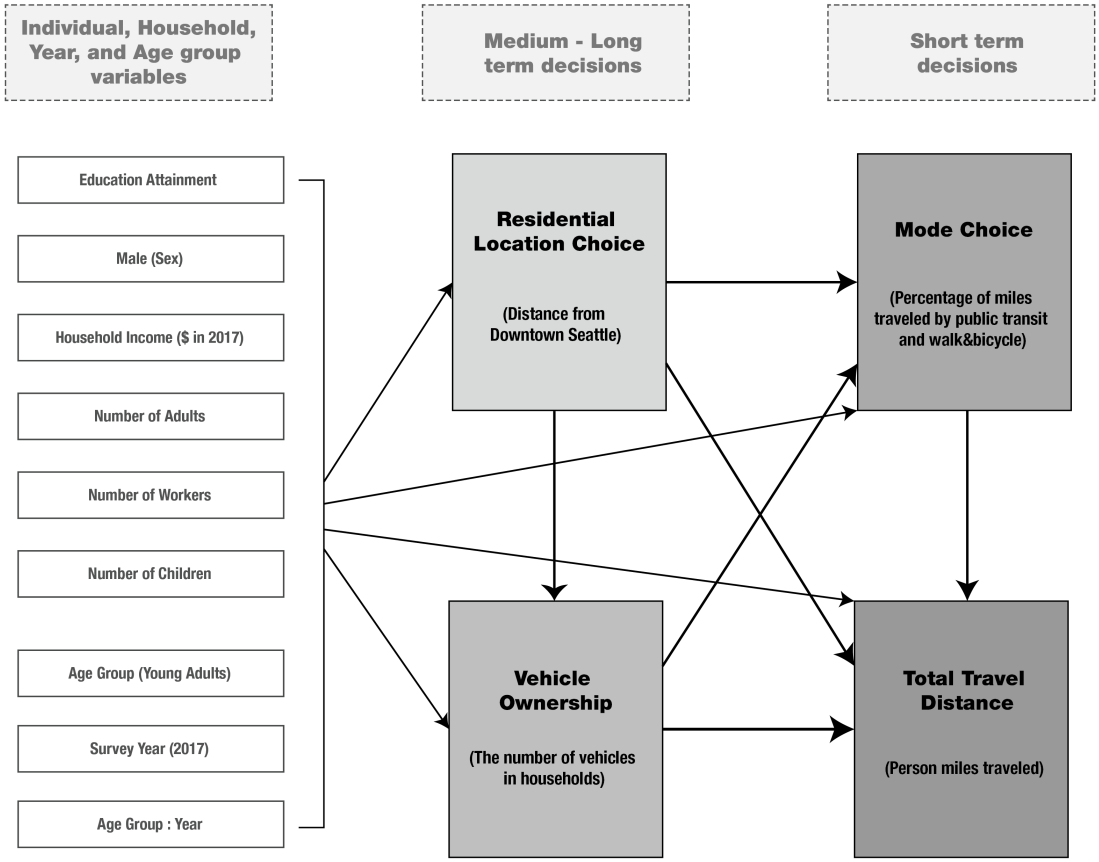

Figure 2: Path diagram connecting household and individual variables to residential, vehicle ownership and travel decisions

a residential choice, a subsequent decision can be made to remain at the same number of vehicles, or to reduce/increase based on the chosen location. These two variables, *RD* and *V*, are then expected to bear on short term decisions. We assume people make mode decisions and how much travel to undertake based on where they live, how many vehicles are available to them, and other personal and household circumstances. Mode choice (*M*) here is measured as the percentage of total distance covered by non-automobile modes. The total travel distance is the reported person miles for the individual during the survey period (*PM*). Both *M* and *PM* are expected to depend on *RD*, *V* and individual and household attributes. The four regression equations that comprise the structural model are given below:

$$RD_h = \alpha_0 + \alpha_1 S_h + \alpha_2 W_h + \alpha_3 C1_h + \alpha_4 C2_h + \alpha_5 C3_h + \alpha_6 I_h + \alpha_7 E + \alpha_8 A_h + \alpha_9 Y + \alpha_{10} A_h : Y \quad (1)$$

$$V_h = \beta_0 + \beta_1 RD_h + \beta_2 S_h + \beta_3 W_h + \beta_5 C1_h + \beta_5 C2_h + \beta_6 C3_h + \beta_7 I_h + \beta_8 E + \beta_9 A_h + \beta_{10} Y + \beta_{11} A_h : Y \quad (2)$$

$$M_i = \gamma_0 + \gamma_1 RD_h + \gamma_2 V_h + \gamma_3 E_i + \gamma_4 X_i + \gamma_5 S_h + \gamma_6 W_h + \gamma_7 C1_h + \gamma_8 C2_h + \gamma_9 C3_h + \gamma_{10} I_h + \gamma_{11} 8A_i + \gamma_{12} Y + \gamma_{13} A_i : Y \quad (3)$$

$$PM_i = \lambda_0 + \lambda_1 RD_h + \lambda_2 V_h + \lambda_3 M_i + \lambda_4 E_i + \lambda_5 X_i + \lambda_6 S_h + \lambda_7 W_h + \lambda_8 C1_h + \lambda_9 C2_h + \lambda_{10} C3_h + \lambda_{11} I_h + \lambda_{12} A_i + \lambda_{13} Y + \lambda_{14} A_i : Y \quad (4)$$

For clarity, we use the subscript h for household level variables and i for individual/decision-maker level variables. Distance from residential location to downtown Seattle (RD_h) is modeled as a function of whether the household has only one adult (S_h), the number of workers in the household (W_h), number of children under 5 years old ($C1_h$), number of children between 5 and 15 years old ($C2_h$), number of children between 16 and 17 years old ($C3_h$), household income (I_h), householder's education (E_h), householder's age group (A_h), the year of survey (Y), and interactions between householder's age group and the survey year ($A_h : Y$). Interactions in the model are included to examine age group specific shifts in choice trends between two years. The number of vehicles in a household (V_h) in turn depends on the residential distance (RD_h) and all of the prior household level variables. Both mode choice (M_i) and person miles traveled (PM_i) are individual variables. Hence, they are modeled as a function of individual's age group (A_i), sex (X_i), education (E_i) as well as household level variables such as income, number of workers, and number of children.

The estimation was done using the Stata software (StataCorp 2015). Since the survey sampling weights are used in the estimation, Stata estimates standard errors using the robust/sandwich estimator. As a result, only the coefficient of determination (CD) and the standardized root mean squared residual (SRMR) are reported as overall goodness of fit measures (StataCorp 2019). Equation level goodness of fit measures are also reported. Table 2 reports the goodness of fit measures. The coefficient of determination (CD), an overall R^2 value for the model, is 0.524. The SRMR for the model is 0.009 where SRMR values below 0.08 indicate a good fit. Equation level R^2 values for the four models are 0.125 (residential location choice), 0.423 (vehicle ownership), 0.143 (mode choice), and 0.107 (travel distance), respectively. Based on these measures, the proposed model fits the data well. The model estimates are presented in Table 3.

Table 2: Model goodness of fit measures

Equation-level goodness of fit				
Model	Fitted Variance	Predicted Variance	R-squared	MC *
Residential location choice (RD_h)	109.388	13.700	0.125	0.354
Vehicle ownership (V_h)	1.222	0.517	0.423	0.651
Mode choice (M_i)	1175.141	167.549	0.143	0.378
Travel distance (PM_i)	474.409	50.687	0.107	0.327
Overall			0.524	
Overall goodness of fit				
Size of residuals				
SRMR	0.009	Standardized Root Mean Squared Residual		
CD	0.524	Coefficient of Determination		

* MC: Correlation between the dependent variable and its prediction

Table 3: Results of the structural equation model - direct, indirect, and total effects

	Original			Standardized		
	Direct E.	Indirect E.	Total E.	Direct E.	Indirect E.	Total E.
Equation 1: RD, Residential distance from downtown Seattle						
Individual and household variables						
Intercept	20.06 *	-		1.92 *	-	
One adult household	-0.15	-	-0.15	-0.01	-	-0.01
Number of workers	1.90 *	-	1.90 *	0.14 *	-	0.14 *
Number of children <5	0.99	-	0.99	0.04	-	0.04
Number of children 5-15	0.61 .	-	0.61 .	0.05 .	-	0.05 .
Number of children 16-17	-0.48	-	-0.48	-0.01	-	-0.01
Household income ($1,000)	-0.03 *	-	-0.03 *	-0.16 *	-	-0.16 *
Bachelor's degree or higher (householder)	-5.84 *	-	-5.84 *	-0.26 *	-	-0.26 *
Age, year, and interaction						
Young adult (householder)	-2.03 *	-	-2.03 *	-0.08 *	-	-0.08 *
Year2017	1.39 .	-	1.39 .	0.07 .	-	0.07 .
Young adult : Year2017 (householder)	-1.23	-	-1.23.	-0.04	-	-0.04
Equation 2: V, Number of vehicles owned by household						
Individual and household variables						
Intercept	1.08 *	-		0.97 *		
One adult household	-0.73 *	-0.002	-0.73 *	-0.26 *	-0.001	-0.26 *
Number of workers	0.39 *	0.03 *	0.42 *	0.28 *	0.02 *	0.30 *
Number of children <5	-0.21 *	0.02	-1.88 *	-0.08 *	0.01	-0.08 *
Number of children 5-15	-0.02	0.01 .	-0.01	-0.15	0.01.	-0.01
Number of children 16-17	0.33 *	-0.01	0.32 *	0.09 *	-0.002	0.08 *
Household income ($1,000s)	0.01 *	-0.001 *	-0.01 *	0.25 *	-0.03 *	0.22 *
Bachelor's or higher degree (householder)	-0.17 *	-0.10 *	-0.27 *	-0.07 *	-0.04 *	-0.12 *

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	Original			Standardized		
	Direct E.	Indirect E.	Total E.	Direct E.	Indirect E.	Total E.
Age, year, and interaction						
Young adult (householder)	-0.26 *	-0.03 *	-0.29 *	-0.10 *	-0.01 *	-0.11 *
Year2017	-0.16 *	0.02 .	-0.14 *	-0.07 *	0.01 .	-0.06 *
Young adult : Year2017 (householder)	-0.21 .	-0.02	-0.23 *	-0.07 *	-0.01	-0.07 *
Endogenous variables						
Distance from Seattle	0.02 *	-	0.020 *	0.16 *	-	0.16 *
Equation 3: M, Percentage of miles traveled by non-automobile modes						
Individual and household variables						
Intercept	37.45 *	-		1.09 *		
One adult household	-9.99 *	7.04 *	-2.95	-0.11 *	0.08 *	-0.03
Number of workers	0.53	-4.93 *	-4.40 *	0.01	-0.11 *	-0.10 *
Number of children <5	-4.40 *	-1.31 *	-3.08	-0.06 *	0.02 *	-0.04
Number of children 5-15	-0.83	-0.20	-1.03	-0.02	-0.005	-0.02
Number of children 16-17	4.28	-2.78 *	1.50	0.04	-0.02 *	0.01
Household income ($1,000s)	0.03	-0.03 *	-0.001	0.04	-0.04 *	-0.002
Bachelor's or higher degree	4.70 *	-	4.70 *	0.07 *	-	0.07 *
Sex (male)	1.93	-	1.93	0.03	-	0.03
Age, year, and interaction						
Young adult	4.34 *	-	4.34 *	0.06 *	-	0.06 *
Year2017	-0.48	0.63	0.15	-0.01	0.01	0.002
Young adult : Year2017	5.36	-	5.36	0.06	-	0.06
Endogenous variables						
Distance from Seattle	-0.49 *	-0.16 *	-0.65 *	-0.15 *	-0.05 *	-0.20 *
The number of vehicles	-9.52 *	-	-9.52 *	-0.31 *	-	-0.31 *
Household level variables						
Bachelor's degree or higher (householder)		5.42 *	5.42 *		0.07 *	0.07 *
Young adult (householder)		3.75 *	3.75 *		0.05 *	0.05 *
Young adult : Year2017 (householder)		2.77 *	2.77 *		0.03 *	0.03 *
Equation 4: PM, total person miles of travel						
Individual and household variables						
Intercept	18.43 *			0.95 *		
One adult household	-1.90	-0.84	-2.75	-0.03	-0.02	-0.05
Number of workers	-0.73	1.70 *	0.98	-0.03	0.06 *	0.04
Number of children <5	-1.39	0.40	-0.99	-0.03	0.01	-0.02
Number of children 5-15	0.37	0.33	0.70	0.01	0.01	0.03
Number of children 16-17	2.25	0.10	2.35	0.03	0.001	0.03
Household income ($1,000s)	0.01	-0.01	0.001	0.02	-0.02	0.04
Bachelor's degree or higher	6.99 *	-0.29 *	6.70 *	0.16 *	-0.01 *	0.15 *
Sex (male)	2.99 *	-0.12	2.87 .	0.07 *	-0.003	0.07 .
Age, year, and interaction						
Young adult	1.24	-0.27 .	0.97	0.03	-0.01.	0.02
Year2017	-1.56	0.45	-1.11	-0.04	0.01	-0.03
Young adult : Year2017	-3.97	-0.33	-4.31	-0.07	-0.01	-0.08

(continued on next page)

	Original			Standardized		
	Direct E.	Indirect E.	Total E.	Direct E.	Indirect E.	Total E.
Endogenous variables						
Distance from Seattle	0.46 *	0.06 *	0.52 *	0.22 *	0.03 *	0.25 *
The number of vehicles	1.31	0.59 *	1.91 *	0.07	0.03 *	0.10 *
Pct of miles traveled by non-automobile modes	-0.06 *	-	-0.06 *	-0.10 *	-	-0.10 *
Household level variables						
Bachelor's degree or higher (householder)		-3.37 *	-3.37 *		-0.07 *	-0.07 *
Young adult (householder)		-1.55 *	-1.55 *		-0.03 *	-0.03 *
Young adult : Year2017 (householder)		-1.04 *	-1.04		-0.02	-0.02
The number of observations					6,855	
Significance: * < 0.05, . < 0.1						

4.1. Residential location choice

The residential location choice model shows that a householder's higher education level and higher household income are associated with closer residential distances to downtown. If the householder held a bachelor's degree or higher, the household lived about 6 miles closer to downtown on average, all other things equal. For each additional $10,000 of household income, the household's residential location were 0.3 miles closer to downtown. Distance to downtown increased as the number of workers in a household increased. Looking at the standardized direct effects where a 1 unit change is equal to a move of 1 standard deviation, these three variables had the most impact on residential distance. When education rose by one unit, residential distance declined by 26% of its standard deviation, a one unit increase in income reduced residential distance by 16% of its standard deviation and a one unit increase in number of workers increased residential distance by 14% of its standard deviation. A peculiar finding was the effect of the presence of children on residential distance. We had expected that increases in the number of school-aged young children would be associated with suburban location choice and therefore an increase in residential distance. However, the variable had no statistically significant impact on residential distance.

Looking at the age group and period effects, we find that young adults chose locations closer to downtown than their older counterparts. The standardized effect of being young adults was a reduction of 8%. Period effects were positive but only significant at the 0.1 level and period by year interactions were not significant. In sum, the model says young adults in both periods lived closer to downtown on average all other things equal. After controlling for other household effects, the residential location choice measured by the distance to downtown between young adults in 2006 and those in 2017 were not different.

As we noted earlier, the top age range of the young adult group in 2017 includes people who were also in the range of 18-24 in 2006. The insignificance of the variable suggests that the young of 2017 are on average not much different from those in 2006.

4.2. Vehicle ownership

The number of vehicles in a household is more strongly associated with socioeconomic and age group variables. On the basis of the standardized coefficients, the largest direct positive impacts were due to the number of workers, income, distance from Seattle and the number of children between 16 and 17 years of age. All of these increased the expected number of vehicles in a household. Households where there was only one adult or a householder has a bachelor's or higher degree had fewer vehicles as expected. Those with more children under age 5 had fewer vehicles.

The vehicle ownership model suggests that there are strong period and age group effects. Young adults had fewer vehicles. In 2017, fewer vehicles were on average expected for any household all other things equal. There was also an add-on interaction where the young in 2017 had fewer vehicles. The standardized effect of being a young adult household in 2006 is a 10% of SD reduction in the number of vehicles while that for a 2017 young adult household is a 24% reduction, all other things equal. These findings are consistent with the broader literature on young adults, particularly Millennials.

4.3. Mode choice

The dependent variable for the mode choice model is the proportion of miles traveled by non-automobile modes on the survey day. The direct effects of the exogenous individual and household variables were small in scale. Households with only one adult tended to have a higher proportion of travel by automobiles as do those with children less than 5 years old. Higher education was associated with a higher level of non-automobile mode use. Number of workers, income, and sex do not have a statistically significant impact.

The age group effect suggested that young adults on average had a higher proportion of travel that was by a non-automobile mode in both 2006 and 2017. However, there were no period effects or the period by age group interactions. The 2006 young adults were no different from the 2017 young adults; older adults in 2006 were also not different from those in 2017 even though the population of young and old adults has changed through aging over the course of the 11 years between these two surveys.

Larger impacts were observed from the distance and number of vehicles variables. As

distance increased by 1 unit, the proportion of non-automobile mode use reduced by 15% of its standard deviation. The total effect of the distance is estimated at a 20% of standard deviation reduction. Number of vehicles had a higher impact, where a 1 standard deviation increase reduced the percentage of miles by non-automobile modes by 31% of its standard deviation.

While we find no direct age-group or period difference on mode use for the individual, the model shows that householder status of being young and period effects have strong indirect effects on non-automobile mode use. Being a young adult household increased the percentage of miles by non-automobile modes by 5% in 2006 and the overall effect on those from a young household in 2017 was an increase of 8% of standard deviation. Householder education also had a 7% of standard deviation indirect impact to increase the percentage of miles by non-automobile modes. These effects are carried through the endogenous residential location and the vehicle ownership variables.

4.4. Travel distance

The person miles travelled (PMT) model shows that the key demographic and socioeconomic variable which directly affected longer travel distance were sex and education level. Being male had a 7% of standard deviation impact on the increase of PMT and having a bachelor's or higher degree increased PMT by 16%. Other exogenous variables did not have a statistically significant impact on PMT. No differences were also seen between young and older individuals, by period, or by period and young interactions. Person miles traveled was significantly impacted by distance from downtown which had a direct impact of 22% of standard deviation and an overall impact of 25% of standard deviation increase for a 1 unit increase. A one unit increase in non-automobile model use decreased by 10% PMT of standard deviation. Number of vehicles did not have a significant direct impact, but its overall impact was significant and was estimated at 10%.

Similar to the the mode use model, the household age group had significant indirect impacts. Those from young adult households had lower PMT in both 2006 and 2017 on the order of 3% of standard deviation. Householder's education also led to a reduction of 7% of standard deviation.

4.5. Direct and Total Effects of Age Group

Overall, our findings show that age group and period effects more strongly influence location choice, vehicle ownership and mode use than they do travel distance. These impacts are shown in Figure 3 along with the impacts of education and income. On residential

distance, the largest impacts come from education and income. Age group membership also has a significant but smaller impact on the location choice. As we showed in Table 1, a high percentage of young adults have at least a bachelor's degree. Younger people's incomes have also grown markedly in 2017. It is clear that for a young high-income, high education individual, these variables have more influence on residential distance to city than age group.

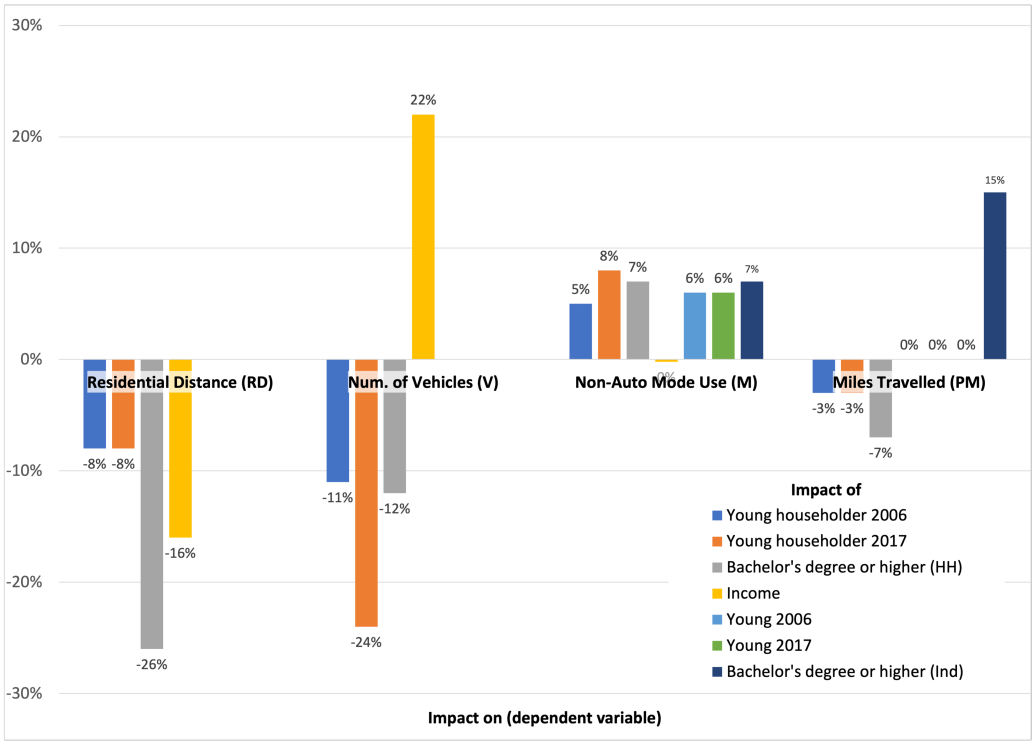

Figure 3: Standardized total impact of a 1 standard deviation change in exogenous variables expressed as a percentage of standard deviation of the dependent variable

The age group effect is much larger on vehicle ownership particularly in 2017. More than any other variable, it appears to be associated with a decline in vehicle ownership, all other things equal. Some of this effect is indirect, flowing through age's impact on residential choice. Higher education also has an overall effect of reducing number of vehicles. Income, on the other hand, has the opposite overall effect and increases vehicle ownership substantially.

Membership in the young age group increases reliance on non-automobile modes with separate impacts from the householder's age (indirectly through the residential location and the vehicle ownership) and the directly from the individual's age group. When both

the householder and the traveler are young, these age effects are additive and become large. Higher education (bachelor's degree or higher) at the household and individual levels also increases non-automobile mode use. On the other hand, income has no overall impact. Finally, age group appears to have small and only indirect impact on person miles traveled. Higher education at the household level reduces person miles indirectly but the individual's education level increases it.

Figure 4 shows the relationship between the four endogenous variables and highlights how the indirect effects are carried through to the down stream variables. Changes in residential location lead to a rise in the number of vehicles, a decline in non-automobile mode use, and an increase in person miles travelled. A reduction in residential distance does the opposite, lowering number of vehicles, increasing non-automobile mode use and reducing miles traveled. Increasing number of vehicles is associated with a reduction in non-automobile mode use and an increase in miles traveled. Increases in non-automobile mode use are associated with a decline in miles traveled. The directions of the relationship are consistent with our conceptual expectations and the expectations of policies that seek to use urban form (denser, city like environments, for example) to effect travel behavior changes.

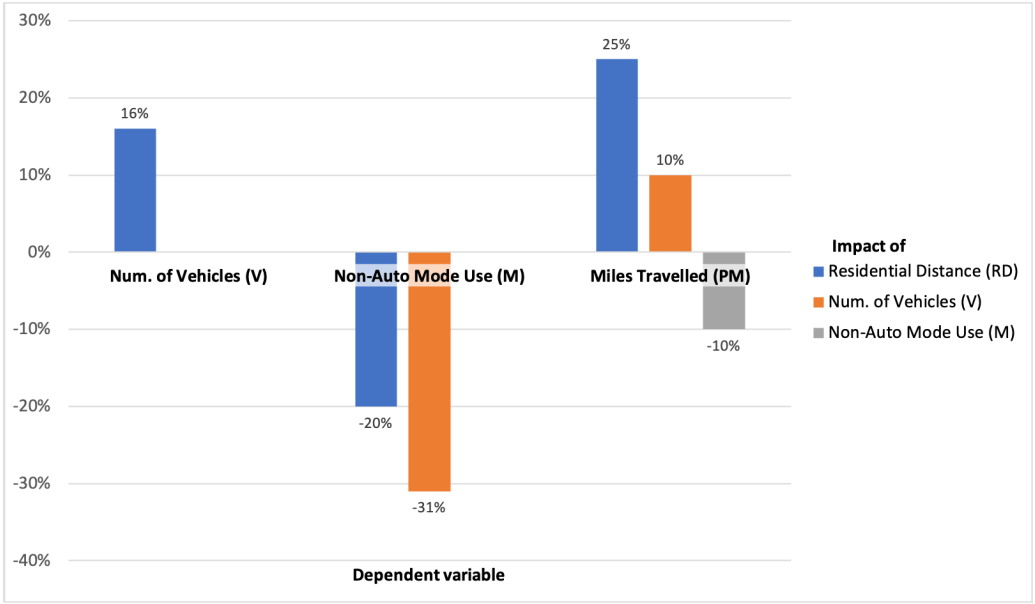

Figure 4: Standardized total impact of a 1 unit change in the endogenous variables expressed as a percentage of standard deviation of the dependent variable

Relative to the literature on the changing behavior of young adults, the largest change we

detect is that young householders in 2017 had fewer vehicles than their younger counterparts in 2006. The overall impact of being young on residential distance from the city center has not changed between 2006 and 2017. The direct impacts of being young on non-automobile mode use do not change between 2006 and 2017. The change in the indirect impact of householder's age on travel decisions between 2006 and 2017 is driven by the strong negative effect of being young on automobile ownership in 2017. Overall, the residential distance and automobile ownership impacts of being a young householder are more consequential to person miles traveled than the direct impacts of age on this variable. The residential distance and automobile ownership impacts of being a young householder on mode use are equivalent or slightly larger than the direct effects of being young.

Our findings also show that residential preferences have strong impacts on transportation related variables as shown in Figure 4. Relative to the self-selection literature which suggests that people choose areas that align with their travel preferences, our results suggest that age plays a sorting role whereby young adults choose locations proximate to the city center. This in turn lowers the number of vehicles at the household level, increases the amount of non-automobile travel and lowers their person miles traveled. Particularly on auto-ownership and non-automobile travel, this sorting effect complements the direct impacts of being a young householder or a young traveler.

5. Conclusion and Discussion

This study examined the impact of age group membership on residential location, vehicle ownership and the travel behavior of young adults using data from the Seattle area. By framing the analysis using the time-horizon of the residential, vehicle ownership and travel decisions, we estimate a path model that disentangles how age group and time period affected location and travel decisions among young adults. Consistent with the broader literature on young adults, we find that young adults in 2006 and 2017 in this data lived closer to the city on average, owned fewer cars, used non-automobile modes more and had lower person miles traveled when compared to older adults.

Young adults in 2017 also exhibited lower auto ownership and higher use of non-automobile modes as compared to young adults in 2006. In other ways, the 2006 and 2017 young adults behaved similarly. Due to limitations in the way the age variable was collected, there is some age overlap in the 2006 and 2017 young adults. While the 2017 young age group is mostly composed of individuals who were younger than 18 in 2006, it also includes people who were between the ages of 18-24 in 2006. This overlap might underestimate the difference between the periods.

Our findings show how interconnected residential choice, vehicle ownership and travel outcomes are. Age group membership influences each of these variables directly. Further, its influence on residential distance indirectly influences vehicle ownership and travel behavior. By following this chain of direct and indirect impacts, we show that age group membership had large impacts on residential choice and vehicle ownership. When it comes to mode use and person miles traveled, the indirect impacts of age group (mediated through residential ownership and vehicle ownership) are often larger than the direct impacts. The overall impacts of residential distance and vehicle ownership on mode use and miles traveled were large. It is clear that changes in these variables, what ever its cause may be, would have substantive impacts on the travel related variables.

Higher education and income also stood out as important variables that influence the types of residential and transportation choices associated with young adults in the recent literature. Both variables positively influenced living closer to the city center. Higher education in particular also lowered vehicle ownership and increased non-automobile mode use. The broader literature emphasizes the higher education of young adults and our results also show that the tendency to live closer to the city and to own fewer cars is strengthened by this variable.

Taken as a whole, we showed that age group membership was an important variable in influencing location, vehicle ownership decisions, mode use and to a lesser extent miles traveled. Young adults were likely to live closer to the city center, to own fewer vehicles, to use non-automobile modes more and to have lower person miles travelled. We also demonstrate that young adults in 2006 and 2017 exhibited similar behaviour except on vehicle ownership. Their choices were however different from their older counterparts in both periods. Our findings also suggest that an important part of what we observe as young adults' travel behavior is associated with what the household is doing in terms of residential location and vehicle ownership. While age group membership had varying levels of impact on all variables considered, its influence on travel decisions in particular was smaller than the effects of residential distance or vehicle ownership. As a result, we think exogenous changes in residential location patterns or vehicle ownership could have large impacts on travel outcomes that exceed the impact of age group membership. This means, if decisions about residential location or vehicle ownership shift to prefer more suburban locations or higher car ownership, for example due to the COVID-19 pandemic or other factors, we should expect significant changes in mode use and miles traveled.

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