Generational Patterns of Modal Shares Across Megaregions

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16. Abstract
Millennials are the largest generation in the current U.S. population. Their travel preferences and choices have profound implications for travel industry and transportation policy-making. The existing literature, however, has presented mixed findings on whether Millennials differ from their preceding generations in vehicle usage, walking or biking, and transit riding. This study examines individuals' modal shares of daily travel by Millennials, Generation X, and Baby Boomers across megaregions. Results of the study show the varying trends of modal shares in different life stages between generations. The varying trends of modal shares over the age spectrum across generations highlight the importance of having cohort-tailored initiatives to achieve sustainable transportation objectives. The study's quantification of megaregional and generational variations on modal shares provides useful information for modal split analysis and other transportation planning practices at the level between states and metropolitan areas.

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Executive Summary

Millennials are able to shape the future transportation market because they have become the largest generation in the current U.S. population. Media reports have highlighted that Millennials differ greatly from the preceding generations, i.e., Generation X and Baby Boomers. If Millennials indeed differ significantly from the older generations, transportation supply and policies should change accordingly. While most existing studies investigate generational travel at the national level, and few have explored the spatial variation of travel by generations at the subnational scale. This study was motived to further understand the generational differences in travel behavior across megaregions in the U.S. This study constructed a unique dataset that combines six national surveys and estimated multilevel models of travel mode shares. Specific findings and conclusions were drawn to help provide insights for transportation planning and policymaking.

Key findings of this research include:

(1) Millennials in adulthood maintain the highest walk/bike share and the lowest share of vehicle travel among all generations.

(2) Megaregional variations exert differentiated influences on individuals' mode share patterns across generation subgroups.

(3) The varying trends of modal shares over the age spectrum across generations highlight the importance of having cohort-tailored initiatives to achieve sustainable transportation objectives.

(4) The study's quantification of megaregional and generational variations on modal shares provides useful information for modal split analysis and other transportation planning practices at the level between states and metropolitan areas.

Chapter 1. Introduction

Millennials have become the largest generation in the current U.S. population, overtaking Baby Boomers and Generation X (The Council of Economic Advisers, 2014). Media reports have highlighted many unique lifestyle characteristics associated with Millennials. For example, Millennials are observed to be ethnically and racially diverse, make delayed life stage decisions on employment, marriage, and parenting, prefer urban locations for homes, and tend not to travel much (Fry et al., 2018; Polzin et al., 2014; The Council of Economic Advisers, 2014). Of particular interest to transportation planners and policy- makers is Millennials' travel preferences and choices. If Millennials indeed differ significantly from the older generations, transportation supply and policies should change accordingly. This interest in Millennials' travel compared with other generations has led to extensive studies. The literature, however, has so far reported mixed findings. Some studies show that Millennials own fewer cars and drive fewer vehicle miles traveled (VMT) than Baby Boomers and Generation X (Choi et al., 2017; D. G. Circella et al., 2016; G. Circella et al., 2017; Klein & Smart, 2017; McDonald, 2015; K. Wang & Akar, 2020). Others argue that the observed generational differences in car ownership and VMT largely disappear once the confounding effects of socioeconomic and demographic factors are controlled (da Silva et al., 2019; Knittel & Murphy, 2019). Still, others report that the observed decrease in driving by Millennials has not been accompanied by the expected increase in transit usage (McDonald, 2015). Some find that Millennials tend to use active transportation and shared ride modes more often than the older generations (Choi et al., 2017; da Silva et al., 2019; X. Wang, 2019). Most existing studies investigate generational travel at the national level. Few have explored the spatial variation of travel by generations at the subnational scale, although some incorporate neighborhood and metropolitan built environmental variables as controls (Brown et al., 2016; X. Wang, 2019). Further research is needed to better understand Millennials' travel behavior for the interest of better informing decisions on transportation infrastructure and mobility services.

Analyzing generational travel behavior should take into consideration simultaneously three basic types of effects: age effects, period effects, and cohort effects. Age effects refer to those associated with the physiological changes, accumulation of social experience, and change in life status as people grow older. Some scholars characterize specific aspects of age effects as demographic effects, which refer to lifestyle-related shifts and changes (da Silva et al., 2019; Krueger et al., 2019; McDonald, 2015). Period effects denote the impacts associated with the societal and technological context that affect all people in the same time period. Cohort effects refer to those associated with groups of individuals who share historical or social experience (Yang & Land, 2008). The common practice for demographic analysis defines cohorts by five-year intervals of people's age. Generation effects are specific types of cohort effects for which cohorts are defined by the birth years of generations. The spatial context presents a fourth type of effects affecting people's travel decisions (Arbués et al., 2016; da Silva et al., 2019). The existing studies on generational travel have considered these four types of effects, but mostly partially.

This study aims to expand the empirical knowledge on Millennials' travel by considering all of the above four types of effects. This is achieved by constructing a unique dataset that combines six national surveys from 1977-2017 and estimating multilevel models of travel mode shares. The study explores the spatial effects at the megaregional scale (see details in Methods section on megaregion definition). After the introduction, the paper reviews related literature. Next, the paper describes the assembled data from Nationwide Personal Transportation Survey (NPTS)/National Household Travel Survey (NHTS) and the analytical methods used for the study. The analysis results and findings are then presented, followed by discussions and concluding remarks on the study findings' implications for transportation planning and policies.

Chapter 2. Literature Review

There are two tales regarding Millennials' travel compared with other generations. The first one suggests that generation effects play a major role; there exist generational shifts in preferences and values, which explain why Millennials prefer cities and embrace transportation alternatives (i.e., use public transit, walk, bike) rather than car (Choi et al., 2017; X. Wang, 2019). The second one points to period effects; factors such as economic recessions and advance in information and communications technologies (ICTs) determine Millennials' travel outcome (Delbosc & Ralph, 2017).

Krueger et al. (Krueger et al., 2019) found that, in Germany, the increase in public transit and bicycling usage from 1998 to 2016 could be all or largely ascribed to generation effects. From a study in the Greater Montreal, Grimsrud and El-Geneidy (Grimsrud & El-Geneidy, 2014) found two parallel trends in transit share of young people. First, within the generation, transit share would decrease as they age. Second, between generations, the transit share would remain higher for the younger generations than others. Generation effects may originate from the intrinsic preference among the individuals of the same generation cohort, e.g., Millennials' lower value of travel time and higher willingness to pay to use ICTs or conduct multitask while onboard (D. G. Circella et al., 2016; Malokin et al., 2021).

Different from the theory of generation effects, life cycle theory suggests that each life stage is associated with different social roles and presents a different attitude system (Erikson, 1993). Mode shares respond to the changes in life cycle sensitively, e.g., mobility tool changes, family and household structure changes (Kitamura, 2009). These factors are referred as demographic effects by McDonald (McDonald, 2015). McDonald (McDonald, 2015) and Krueger et al. (Krueger et al., 2019) argue that it is the generation effects and period effects, not demographic effects, that take the major role in impacting modal usage. Yet Brown et al. (Brown et al., 2016) reached the opposite solution. From their study using the 2001 and 2009 NHTS data, the authors conclude that higher public transit trips by young adults result mostly from life cycle, demographic and locational factors rather than from period or generation effects. Specifically, Millennials have no particular preference for transit. The authors stress that, if the average transit use would remain high as people age, it is more likely due to the demographic transition than to the increase in preference for transit. da Silva et al. (da Silva et al., 2019) reached a similar conclusion from their analysis of VMT. K. Wang et al. (K. Wang et al., 2018) highlight the importance of age effects, stating that old individuals have different travel preference due to changed perception of external physical and natural environment.

Period conditions, i.e., the state of the macroeconomic environment, have been found to influence future travel to a great extent (Blumenberg et al., 2016). Period effects interwind with generational and demographic effects in shaping people's travel choice. Studies have shown that Millennials tend to live in urban areas and drive relatively less than other generations. But it is unsure how much the generational differences can be attributed to the severe labor and housing conditions that Millennials face when they start careers. The policy environment is also an important factor affecting travel outcome. Past few decades saw shifts towards less auto-centric transportation policies (Ross, 2011). To what extent do the changes in policy environment contribute to the shift in mode usage by different age groups? Demographic effects also interwind with generation effects, and it is difficult to separate them entirely (da Silva et al., 2019; Krueger et al., 2019).

In the existing research on generational travel behavior, population density and mode supply are two of the most commonly considered factors in the discussion of spatial effects (Brown et al., 2016; X. Wang, 2019). Most studies use national data to make analysis. One exception is the series of studies published based on the California Millennial Survey. These studies found that Millennials had a higher rate of adoption of shared mobility services than others. In addition, Millennials were likely to be multimodal commuters rather than mono-drivers (D. G. Circella et al., 2016; G. Circella et al., 2017). The study by da Silva et al. (da Silva et al., 2019) considers spatial variations of generational travel at the scale of Census Divisions. They found that compact areas such as Middle Atlantic region had fewer VMT than in sprawled areas such as West South Central region. Arbués et al. (Arbués et al., 2016) built a multilevel model considering the spatial context as random effects to explain mode choice. They found that there was significant spatial variation involved with the departure regions. The study observed that the spatial context of trip origins or home locations had significant effects on individuals' travel outcome (Arbués et al., 2016; da Silva et al., 2019). Overall, the discussions on the spatial variations of generational travel behavior have been inadequate. This study attempts to improve understanding of generational travel characteristics by examining the mode share characteristics of Millennials, Baby Boomers, and Generation X across the U.S. megaregions.

Chapter 3. Methods

3.1. Study Geography and Data

A megaregion consists of multiple metropolitan areas and their integrated hinterland (Hagler, 2009). Regional Plan Association (RPA), Federal Highway Administration (FHWA), and many scholars have proposed various ways to delineate megaregions (Federal Highway Administration, 2018; Hagler, 2009). This study follows that provided by RPA, which represents the first group of researchers studying the U.S. megaregions in the new century. **Figure 3.1** illustrates the eleven megaregions defined by RPA. It should be noted that the NPTS/NHTS data does not provide location identifier below MSA (Metropolitan Statistical Area) or CMSA (Consolidated Metropolitan Statistical Area). The megaregion geography considered in this study contains groups of MSA/CMSA, not including those counties that are outside MSA/CMSA but are part of megaregions as RPA initially defined. See Appendix for details on the MSA/CMSA contained in each of the eleven megaregions.

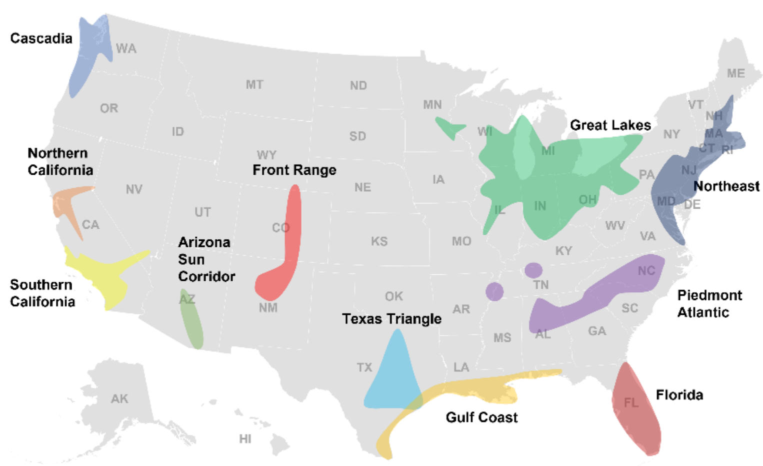

Figure 3.1 Location distribution of 11 megaregions (redrawn from RPA) (Hagler, 2009; Regional Plan Association, 2008)

Eight nationwide travel surveys are available in the United States. They provide the socioeconomic and demographic characteristics of the surveyed persons and households. The daily trip file in each survey includes all trips made by the interviewed person on the assigned travel day. Among eight data sets, six data sets from 1977 and 1990 to 2017 are used in the study since they provide location identifiers at the MSA/CMSA level for the surveyed households.

In nearly four decades of NPTS/NHTS efforts, there have been changes made to the data collection methods and survey administration processes. For example, the 1977 NPTS collected data from 376 primary sampling units distributed across all 50 states and the District of Columbia and administered the survey through in-home interviews and telephone follow-ups. In 1990, the survey was for the first time conducted exclusively by phone interviews. In 1995, a 2-stage survey method (one interview at the household level and one at the person level) was applied to collect household members' travel diaries. This change in survey methods created challenges to compare travel outcomes across surveys. For instance, the 1995 NPTS user guide (Research Triangle Institute, 1997) specifies that, for the observed increases in daily person trips from 3.1 trips in 1990 to 4.2 trips in 1995, 0.4 trips of the increment can be attributed to real increase, and the remaining 0.7 trip increment is due to the change in survey methods. The 2001 NHTS modified survey design to specifically remind respondents to include walk and bikes trips. As a result, walk/bike trips were reported higher than in previous waves of NPTS/NHTS. Hu (Hu & Reuscher, 2005) reports that the percentage of total person trips by foot for social and recreational and other purposes in 2001 almost doubled that in 1995. For the 2017 NHTS, data on trip lengths were derived by applying shortest-path algorithms based on geocoded trip origins and destinations. The GIS-based estimation resulted in about 10% shorter than the self-reported trip lengths collected in prior surveys.

Another concern of combining data from multiple NPTS/NHTS pertains to add-on sampling. Beginning in 1990, additional households have been surveyed in the add-on areas requested by different States and Metropolitan Planning Organizations (MPOs). The add-on areas, the size of additional samples, and add-on questions differ across surveys. For example, the 1990 NPTS included three add-on areas. In the 2017 NHTS, the number of add-on areas increased to thirteen. Since the 1995 NPTS, the additional samples collected for add-on areas have taken up 49.7%~83.0% of the total samples (Westat, 2018). The data tables with add-on samples included raise concerns of geographical oversampling. NPTS/NHTS have provided weighted data to help adjust the potential sample biases. This study uses the weighted sample for descriptive analysis but the unweighted sample for modeling analysis (see explanation in later sections).

The study adopts the most widely used year cutoffs suggested by Pew Research Center (Dimock, 2019) to define Baby Boomers, Generation X, and Generation Y or Millennials (**Table 3.1**). Intra-generational heterogeneity is often taken into account in the generational research (Jamal & Newbold, 2020). This study examines intra-generational travel heterogeneity by dividing the same generation population into two subgroups at the midpoint of the birth year range for each generation.

Mode share is measured as the number of trips by a mode divided by the total number of trips by all modes in the travel day for an individual (Dai et al., 2020). As mentioned above, there have been multiple changes in data collection methods and processes across waves of NPTS/NHTS. However, there have been no guidances from NPTS/NHTS agencies on ways to adjust walk/bike trips since the 2001 survey (NPTS/NHTS agencies have provided explicit guidance to adjust trip length data for the 2017 survey. The trip length data is not directly related to this study though). This study used the raw data from the original NPTS/NHTS while reminding the reader of the potential impacts of variations in survey methods across-NPTS/NHTS.

After excluding the records with missing values, the final dataset contains 413,465 observations. **Table 3.1** reports the summary statistics of the sample.

Table 3.1 Descriptive Statistics (unweighted)

	Variable and definition	min	max	mean	std.dev
	Dependent variable				
Mode Share	Walk/bike trip share	0	1	0.082	0.216
	Vehicle trip share	0	1	0.882	0.271
	Transit trip share	0	1	0.020	0.119
	Independent variable				
Person Attributes	Age (years)	20	71	45.170	13.047
	Gender: 1: Male; 0: Otherwise	0	1	0.471	0.499
	Race: 1: White; 0: Otherwise	0	1	0.841	0.366
	Education level 1: <=high school or GED (General Educational Development)	0	1	0.271	0.445

	Education level 2: some college or associates degree	0	1	0.286	0.452
	Education level 3: bachelor's degree	0	1	0.258	0.437
	Education level 4: graduate degree or professional degree	0	1	0.185	0.388
	Employment status: 1: Have work; 0: Otherwise	0	1	0.759	0.428
	Driver's status: 1: Have driver's license; 0: Otherwise	0	1	0.961	0.193
Household Attributes	Household income (in 2017 U.S. Dollar)	2850	505000	82960.889	48944.763
	Vehicles per person in household	0	27	0.925	0.544
	Percent of drivers in household	0	1	0.796	0.255
	Life cycle status: one or more adults, retired or not retired, no children	0	1	0.561	0.493
	Life cycle status: one or more adults, not retired, youngest children 0-21	0	1	0.439	0.493
	Urban area status: not live in urban area	0	1	0.269	0.443
	Urban area status: live in urban area without rail transit	0	1	0.595	0.491
	Urban area status: live in urban area with rail transit	0	1	0.128	0.332
		min	max	Sample share	Sample size
Geographic Distribution	Arizona Sun Corridor	0	1	0.014	0.117
	Cascadia	0	1	0.007	0.084
	Florida	0	1	0.022	0.148
	Front Range	0	1	0.004	0.064
	Great Lakes	0	1	0.067	0.249
	Gulf Coast	0	1	0.001	0.031
	Northeast	0	1	0.118	0.322
	Northern California	0	1	0.039	0.193
	Piedmont Atlantic	0	1	0.038	0.192
	Southern California	0	1	0.061	0.239
	Texas Triangle	0	1	0.101	0.302
	Not in megaregion	0	1	0.529	0.499
Survey Year Indicat	1977	0	1	0.011	0.106
	1990	0	1	0.033	0.179

	1995	0	1	0.084	0.277
	2001	0	1	0.161	0.367
	2009	0	1	0.337	0.473
	2017	0	1	0.374	0.484
Generation Indicator	Older Baby Boomers (GenBB1; born 1946-1955)	0	1	0.319	0.466
	Younger Baby Boomers (GenBB2; born 1956-1964)	0	1	0.276	0.447
	Older Generation X (GenX1; born 1965-1972)	0	1	0.177	0.382
	Younger Generation X (GenX2; born 1973-1980)	0	1	0.112	0.315
	Older Millennials (GenY1; born 1981-1988)	0	1	0.077	0.267
	Younger Millennials (GenY2; born 1989-1996)	0	1	0.039	0.193
	Number of observations	413,465			

Note:

1. The analyses in Life Stage Trends of Modal Shares by Generations (see details in Results section) use the full sample containing 527,029 observations and a subsample containing 444,618 observations for individuals aged 20 or older. This table shows the summary statistics of the sample used for the multilevel model after excluding the records with missing values.
2. The mean value corresponding to a geographic region indicated the share of the region's sample in the combined dataset.
3. Age was linearly transformed (age/100) to adjust for modeling with comparable scales across regressors. The quadratic form ((age/100)^2) of this term is included in the model to account for non-linearities in its relationship with modal shares.
4. Household income from each surveyed year was inflated to 2017 U.S. Dollars. Household income was transformed with a natural log and then divided by 10 (ln(household income)/10) to account for non-linearities and adjust for modeling with comparable scales across regressors.

3.2. Analytical Methods

The analysis includes two parts. The first part performs graphic comparisons of modal shares in life cycles for generation groups using weighted data. By combining six NPTS/NHTS data, the study is able to graph an average traveler's modal shares by ages ranging from 5 to 36 for Millennials, 5 to 52 for Generation X, and 5-71 for Baby Boomers. Plotting the age-modal share data allows examination of modal share trends in various life stages within and between generations.

The second part of the analysis estimates two-level hierarchical models of modal shares to understand factors contributing to generational differences and spatial variations. In age-cohort-period analysis, many studies incorporate only two of the three variables (age, cohort, period) in the analysis to avoid multicollinearity between these three effects (Choi et al., 2017; Scheiner & Holz-Rau, 2013; X. Wang, 2019)**.** Others specify cohort and period effects as random variables (Krueger et al., 2019; Yang & Land, 2008). This study adopts the multilevel model with generation effects and period effects specified as the random terms to avoid identification problem. Models are estimated using unweighted samples. Because model specifications include some factors used in the weighting process, it is preferred, as shown in previous studies, to model travel outcomes using unweighted data (McDonald, 2015; X. Wang, 2019; Winship & Radbill, 1994).

The study builds a two-level model shown below:

Level 1

$$Y_{ijkm} = \beta_{0jkm} + \sum \beta_{X0} X_i + \sum \beta_{Zm} Z_{im} + \varepsilon_{ijkm} \qquad (1)$$

Level 2

$$\beta_{0jkm} = \beta_{00} + U_{0jm} + U_{0k} \qquad (2)$$

$$\beta_{Zm} = \beta_{Z0} + U_{0m} \qquad (3)$$

where Y_{ijkm} is the modal share for person i in megaregion j, survey year k and generation subgroup m, β_{0jkm} is the intercept for samples in group j, k, and m, β_{X0} are the coefficients of the set of variables X_i. β_{Zm} are the coefficients of the set of variables Z_{im}.

Indicators of megaregions, generation subgroups, and survey years enter the model as level-2 random terms, expressed in Equation (2). Dynamic slope models are specified, as expressed in Equation (3), to capture generational random effects on the factors with important policy and planning implications. These factors include driver status, urban area indicator, and rail transit supply.

Chapter 4. Results

4.1. Life Stage Trends of Modal Shares by Generations

Figure 4.1 plots modal shares by age for Baby Boomers, Generation X, and Millennials. Due to the limitations of data to the NPTS/NHTS years, sample observations are available for all three generations only in the age range of 13-36. There are no observations for Baby Boomers in age 12 or younger and for Millennials in age 37 or older. Accordingly, inter-generational comparisons presented below are limited to Millennials and Generation X at age range of 5-12. This study's interest is mainly Millennials. For the interest of space, the discussions below omit the comparison between Baby Boomers and Generation X aged 37 or older.

During the childhood at ages 5-12, Millennials and Generation X exhibit two contrasting characteristics regarding the modal shares of their daily travel. First, Millennials have lower shares of travel by walking/biking and transit and a higher share of vehicle travel than their counterparts from Generation X. Second, when they grow older from early to late childhood, Millennials display a decreasing trend in the share of vehicle travel, while their shares of travel by transit and non-motorized modes go upwards. Children have mobility constraints, and their travel needs are largely met by, but also influence the travel decisions of their parents. Understanding the contrasting mode choice characteristics between Millennials and Generation X in their childhood requires research on the choice behavior of their respective parent generations, which goes beyond the scope of this paper.

During their teenage stage (13-19 years old), the three generations present similar trends: decreasing in transit and walk/bike shares and increasing in vehicle travel. People in this stage expand travel needs for increasingly diverse daily activities. Some of them begin to obtain a driver's license, which enables them to have more freedom to make their own decisions on mode choice. Notably, during age 13-16, Millennial teenagers show consistently lower transit share but higher vehicle travel share than teenage Baby Boomers and Generation X. During age 17-19, Millennial teenagers have higher vehicle travel share (except for age 17) than two older generations, but their transit share does not differ from those the other generations. For non-motorized travel, Millennials have a higher share than Generation X (except for age 18), whereas Baby Boomers have the highest shares of walk/bike.

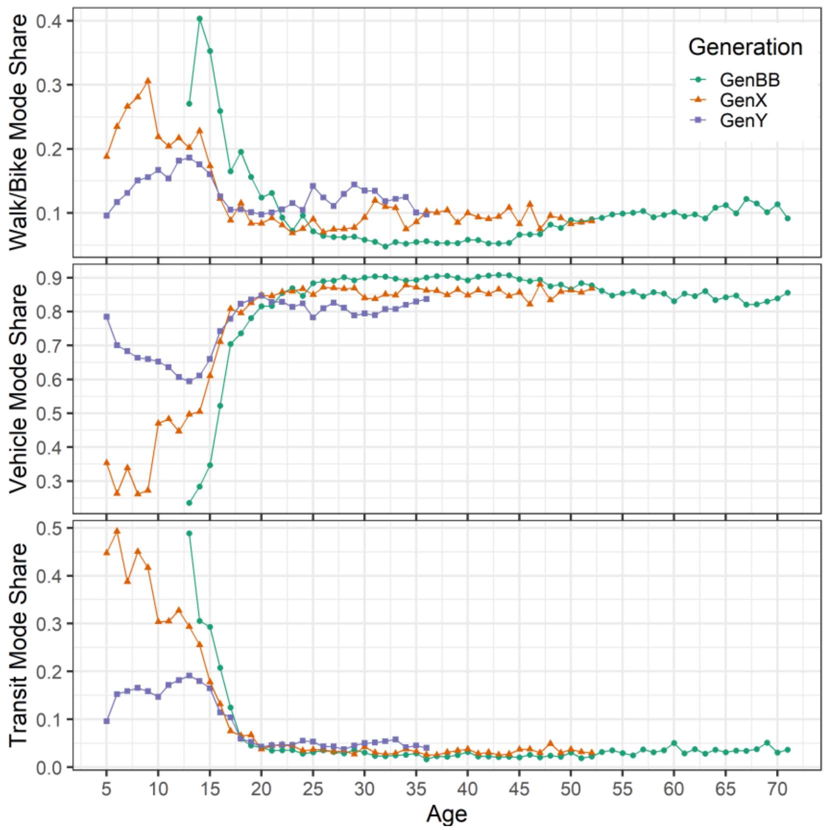

Figure 4.1 Mode shares by age and by generations

After people turn 20, their modal shares appear stable with little radical changes. An interesting observation is that the relative levels of modal shares for the three generations shift to the opposite of those seen in the teenage and childhood years. After age 22, Millennials maintain the highest walk/bike share while Baby Boomers' walk/bike share drop to the lowest level among the three generations. For vehicle share, Millennials shift from having the highest share before age 20 to the lowest after age 22. Numeric analysis, which is presented in the following section, helps assess the generational differences in detail. The difference in vehicle share between the three generations is rather small though. For transit shares, the generational differences seen in childhood and teenage time narrow in the adulthood of the three generations.

Another interesting observation pertains to the turning points on the graphs of the three generations' walk/bike shares. Notably, Baby Boomer's walk/bike curve turns upwards at age 44, and the rising trend persists up to the mid-60s. For Generation X, their walk/bike curve turns upward when they are in late 20s-30s. Millennials exhibit an upward curve of walk/bike share in ages 19-30. These turning points and curve segments of rising walk/bike shares associated with the three generations occurred in the time when a major campaign for active living took place in the United States. In 1996, the U.S. Centers for Disease Control and Prevention (CDC) published the Surgeon's General Report on Physical Activity and Health. In the subsequent year, CDC launched an initiative to promote active living that integrates physical activities into everyday routines such as walking to stores and biking to work. A program called Safe Routes to School (SRTS) was also initiated to encourage children to walk and bike to/from school safely. In 2000, Robert Wood Johnson Foundation launched multifaceted programs to promote active living. The observed increase in walk/bike shares for three generations likely reflects the national active-living campaign.

To explore intra-generational and spatial variations in modal shares, we perform a similar visual analysis to that presented above and graph modal shares across megaregions and generation subgroups (**Figure 4.2**).

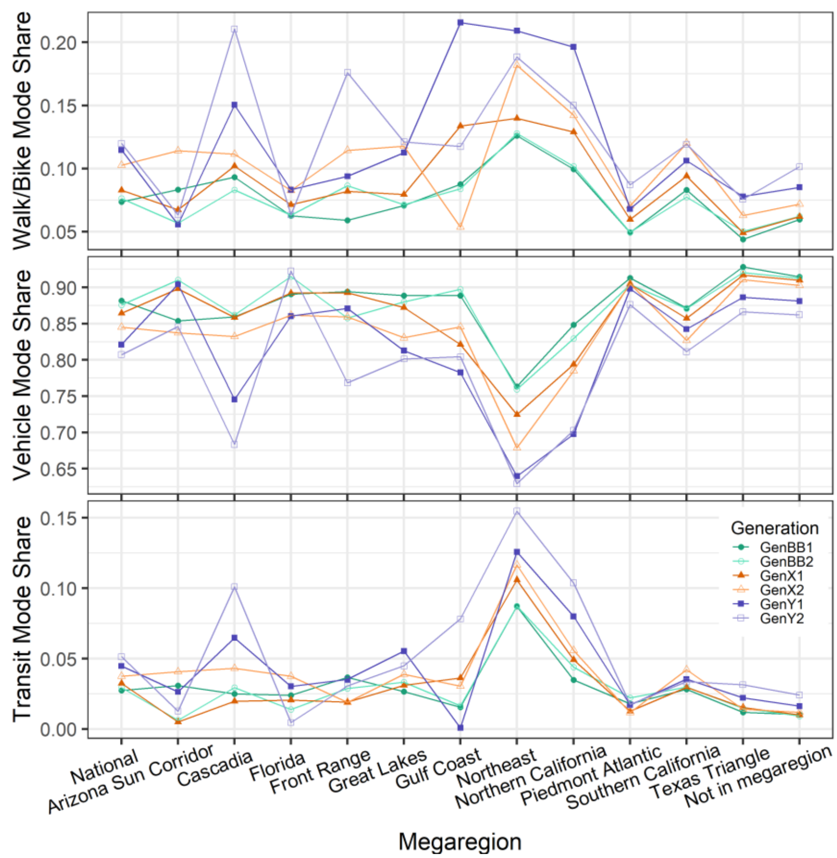

Figure 4.2 Mode shares by megaregions and generation subgroups

Three main observations from **Figure 4.2** are highlighted below.

- There exist noticeable intra-generation differences. At the national level, the younger subgroups of Millennials, Generation X and Baby Boomers tend to have higher shares of walk/bike and transit usage but a lower share in vehicle travel.
- Spatial variations in modal shares are apparent. Northeast, Northern California and Cascadia have the highest transit shares and lowest vehicle shares among all megaregions across most generation subgroups. Piedmont Atlantic, Texas Triangle, and other places not in megaregions have the contrary mode share patterns, i.e., the highest vehicle share and lowest transit share.
- The picture for walk/bike shares is rather complicated across megaregions and generation subgroups. GenY1 in Cascadia, Gulf Coast, Northeast, and Northern California shows a relatively high level of walk/bike share. In Front Range and Cascadia, GenY2 appear to have the highest walk/bike share among all generation subgroups. Baby Boomers in

Northern California and Northeast walk/bike more than their counterparts in other megaregions.

To shed light on what and how factors contribute to the varying mode share patterns, we estimate two-level models of modal shares as described in Methods and present the modeling results below.

4.2. Modeling Results

Table 4.1 reports the multilevel modeling results in two panels. The top panel contains the estimated effects at the individual level. At this level, the coefficients indicate the direction, statistical significance, and magnitude of influence of individual and household characteristics on the modal shares of a person's daily travel. Interpreting level-1 results follows the same conventions as with multiple regression except for the variables that interact with level-2 variables.

Table 4.1 Model Results

	Walk/bike Share		Vehicle Share		Transit Share	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
Intercept	0.432***	0.012	0.268***	0.014	0.251***	0.005
age/100	-0.010	0.025	0.037	0.030	-0.003	0.013
(age/100)^2	-0.078***	0.024	0.093***	0.029	-0.022*	0.013
Male (ref: female)	0.009***	0.001	-0.020***	0.001	0.002***	0.000
White (ref: non-white)	0.013***	0.001	0.006***	0.001	-0.020***	0.001
Education level 2	0.011***	0.001	-0.014***	0.001	0.002***	0.000
Education level 3	0.033***	0.001	-0.038***	0.001	0.005***	0.001
Education level 4	0.055***	0.001	-0.064***	0.001	0.007***	0.001
Employment status: (ref: unemployed)	-0.027***	0.001	0.022***	0.001	0.006***	0.000
ln(household income)/10	-0.137***	0.005	0.203***	0.006	-0.068***	0.003
Vehicles per person in household	-0.035***	0.001	0.049***	0.001	-0.021***	0.000
Percentage of drivers in household	0.010***	0.002	0.008***	0.003	-0.007***	0.001
Have children (ref: not have children)	-0.033***	0.001	0.057***	0.001	-0.019***	0.001
Driver's license status: (ref: not have driver license)	-0.194***	0.005	0.341***	0.008	-0.117***	0.005
Urban area without rail supply: (ref: not in urban area)	0.018***	0.004	-0.021***	0.004	0.002***	0.000
Urban area with rail supply	0.051***	0.007	-0.093***	0.014	0.036***	0.005
Random effects:	**Variance**	**Std.Dev**	**Variance**	**Std.Dev**	**Variance**	**Std.Dev**

Level 1: Residual	0.04296	0.20726	0.06380	0.25259	0.01266	0.11253
Level 2: Survey year (intercept)	0.00045	0.02129	0.00057	0.02377	0.00002	0.00477
Level 2: Megaregion*Generation (intercept)	0.00060	0.02443	0.00199	0.04458	0.00041	0.02030
Level 2: Generation (Driver's license status slope)	0.00011	0.01051	0.00034	0.01833	0.00012	0.01105
Level 2: Generation (Urban area without rail supply slope)	0.00007	0.00843	0.00009	0.00965	0.00000	0.00000
Level 2: Generation (Urban area with rail supply slope)	0.00025	0.01585	0.00121	0.03471	0.00017	0.01304
Number of groups: Survey Year	6		6		6	
Number of groups: Megaregion*Generation	72		72		72	
Number of groups: Generation	6		6		6	
Log Lokelihood	63868.2		-17951.8		316370.8	
Number of obs	413,465		413,465		413,465	

Significant level: <0.01 (***), <0.05 (**), <0.1 (*)

The age coefficients suggest that, as people grow older, their shares of trips by walk/bike and transit tend to decrease while the vehicle travel share goes up, all else being equal. The significant coefficient of the quadratic form of the age term indicates that the age effects on the modal share become larger as age increases. Male travelers appear to use walk/bike and transit modes more than female travelers, a finding that is in line with the results by other studies using NHTS data (X. Wang, 2019). European research (Arbués et al., 2016; Krueger et al., 2019) shows different gender preference in modes though, suggesting national differences. Differences in modal shares between racial groups also exist, with the white having higher driving share and lower transit share than the non-white (Brown et al., 2016). Higher education level is positively associated with larger shares of transit and non-motorized travel. Workers are more likely to drive and take transit but less likely to walk/bike than those who are not employed. As expected, individuals with higher income and vehicle ownership produce a larger share of driving trips (Kitamura, 2009; X. Wang, 2019). The literature has reported that people with children are more likely to use the driving mode than riding on transit (Brown et al., 2016; Krueger et al., 2019). This is reconfirmed by the present study.

Three variables in the fixed effect panel, driver's license status, urban area with no rail transit, and urban area with rail transit, are specified to interact with level-2 variables. Accordingly, their effects on modal shares come from two parts, the fixed effects indicated by the coefficients shown in the top panel of **Table 4.1** and the random effects to be discussed next. For the fixed effects part, the three variables exhibit their influence on modal shares in the expected direction: People with driver's license have a higher probability to choose driving and a lower probability to walk/bike or use transit. Those living in urban area are more likely to use transit. If rail transit is available in the urban area, the transit share goes up further (Brown et al., 2016).

The random effects are attributed to the variation at the group level stratified by generation subgroups, megaregions, and survey years. The bottom panel of **Table 4.1** reports the level-2 random or group effects, which are estimated in the form of random intercepts and random slopes as described in Equations (2) and (3). In the final accepted models, the random intercept specification applies to survey year as well as the interaction term between megaregions and generations. Such specification captures the effects of group-level variations between megaregions, between survey years, and between generations on the average modal shares at the individual level. The random slope specification applies to the three variables described in previous paragraph. The estimates of the random slope effects measure the extent to which the group-level variations modify the fixed effects of the corresponding variables on the modal share outcome. In other words, this model specification enables quantification of the varying marginal effects of the three variables on modal shares across megaregions, generations, and survey years.

Because the modeling output shown in the bottom panel of **Table 4.1** reports only the estimated group-level variances and their standard deviations, post-modeling processing is necessary to calculate the total effects that combine the level-2 random effects with level-1 fixed effects.

4.2.1. Generation Effects

There exit generation-specific effects on modal shares in addition to the effects of socioeconomic factors at the individual level. Most of the generation effects are statistically significant at the 5% or higher level, as shown in **Table 4.2**. Take the Walk/Bike Share model as an example to interpret the results: a person having a driver's license likely has her/his walk/bike share lower than the one without driver's license by 19.4 percentage points on average (shown by the fixed effect coefficient reported in **Table 4.1**). However, the amount would vary depending on which generation the person belongs. If the person comes from the older Baby Boomer group, the total effects of having a driver's license would become 17.5%. For the younger Baby Boomer group, the effect of driving licensure becomes larger at 20.3%. For Millennials, no group-level effects are observed at the 5% level of significance.

Table 4.2 Generation Random Effects and Total Effects

	Driver's license status: (ref: not have driver license)		Urban area without rail transit: (ref: not in urban area)		Urban area with rail transit	
	Random effects	Total effects	Random effects	Total effects	Random effects	Total effects
Walk/Bike Share						
GenBB1	0.019***	-0.175	-0.009***	0.009	-0.016***	0.034
GenBB2	-0.009***	-0.203	-0.007***	0.011	-0.016***	0.035
GenX1	0.006	-0.189	-0.005***	0.013	-0.011***	0.039
GenX2	-0.010***	-0.204	0.001	0.019	0.013***	0.063
GenY1	-0.002	-0.196	0.012***	0.030	0.023***	0.074
GenY2	-0.003	-0.198	0.009**	0.027	0.007	0.058
Vehicle Share						
GenBB1	-0.030***	0.311	0.011***	-0.010	0.038***	-0.055
GenBB2	0.023***	0.363	0.008***	-0.013	0.032***	-0.061
GenX1	0.012***	0.353	0.005**	-0.016	0.026***	-0.067
GenX2	0.009*	0.350	0.001	-0.020	-0.009*	-0.102
GenY1	-0.015***	0.325	-0.012***	-0.033	-0.041***	-0.134
GenY2	0.001	0.342	-0.013***	-0.034	-0.046***	-0.139
Transit Share						
GenBB1	0.014***	-0.103	0.000	0.002	-0.014***	0.022
GenBB2	-0.011***	-0.128	0.000	0.002	-0.009***	0.027
GenX1	-0.015***	-0.133	0.000	0.002	-0.011***	0.025
GenX2	0.001	-0.117	0.000	0.002	0.001	0.037
GenY1	0.012***	-0.105	0.000	0.002	0.013***	0.049
GenY2	-0.001	-0.118	0.000	0.002	0.021***	0.057

Significant level: <0.01 (***), <0.05 (**), <0.1 (*)

Concerning the influence of Urban area with rail transit on Walk/Bike Share, generation effects are significant for all but the younger Millennials. A person from the older Millennials group in an urban area with rail transit likely walks/bikes 4.4 percentage points (0.074-0.030) more than if she/he lives in an urban area without rail transit. For a younger Baby Boomer, the presence of rail transit also matters to her/his walk/bike share but by 2.4 percentage points (0.035-0.011) in difference, or more than half of that for older Millennials. Interpretations are similar for other variables and for the models of vehicle share and transit share but are omitted here. The impact by urban area and rail supply presents to be greater for younger generations. Millennials (GenY1 and GenY2) living in urban area with or without rail services are shown to have higher walk/bike and transit share and lower vehicle share than other preceding generation subgroups. For younger generation subgroups in each generation, the impact by urban area and rail supply presents to be more significant than for the older generation subgroups, except for GenY2 who have a lower walk/bike share than GenY1.

4.2.2 Spatial Effects by Megaregions

Megaregions or clusters of metropolitan areas present agglomeration economies that exert influence on people's travel choice decisions. This study specifies an interaction term between generations and megaregions for the intercept to capture the effects of spatial heterogeneity across generations. **Figure** illustrates the results of the dynamic intercept model. Numbers on the vertical axis of the figure measure the effect size of megaregional and generational variations on the intercept or the average modal share at the individual level. **Table 4** presents the numerical version of **Figure** . Notably, for Walk/Bike share, three megaregions including Cascadia, Northeast, and Northern California display positive estimates across six generation subgroups. It means that people from these three megaregions have higher Walk/Bike shares in their daily travel than the national average, while the varying estimates for six generation subgroups indicate the magnitude of differences measured in percentage points. Conversely, the negative coefficients for other megaregions measure the deviations below the national average. A similar pattern is observable for Transit Share, while the opposite pattern is evident for Vehicle Share.

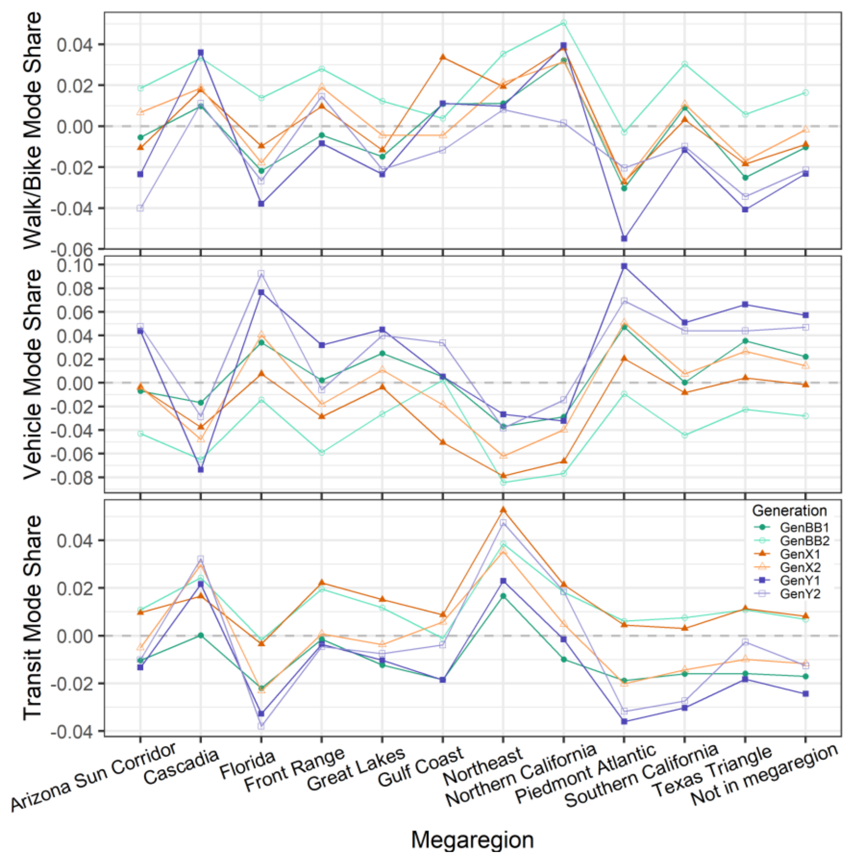

Figure 4.3 Spatial and generation interaction random effects

Table 4.3 Spatial Random Effects

	GenBB1	GenBB2	GenX1	GenX2	GenY1	GenY2
Walk/Bike Share						
Arizona Sun Corridor	-0.005 (-0.891)	0.019*** (2.850)	-0.011 (-1.431)	0.007 (0.822)	-0.023** (-2.342)	-0.040** (-2.564)
Cascadia	0.010 (1.305)	0.033*** (4.253)	0.018* (1.943)	0.019 (1.634)	0.036*** (2.715)	0.011 (0.650)
Florida	-0.022*** (-4.020)	0.014** (2.430)	-0.010 (-1.476)	-0.018** (-2.236)	-0.038*** (-4.127)	-0.027* (-1.886)
Front Range	-0.004 (-0.461)	0.028*** (2.869)	0.010 (0.872)	0.019 (1.511)	-0.008 (-0.564)	0.015 (0.842)
Great Lakes	-0.015*** (-3.263)	0.012*** (2.632)	-0.012** (-2.258)	-0.004 (-0.751)	-0.023*** (-3.560)	-0.021*** (-2.618)
Gulf Coast	0.011 (0.754)	0.004 (0.248)	0.034** (1.980)	-0.004 (-0.229)	0.011 (0.514)	-0.012 (-0.501)
Northeast	0.011** (2.556)	0.035*** (7.933)	0.019*** (4.005)	0.021*** (3.835)	0.010 (1.538)	0.008 (0.988)
Northern California	0.032*** (6.366)	0.051*** (9.747)	0.038*** (6.588)	0.032*** (4.881)	0.040*** (5.788)	0.002 (0.190)

Piedmont Atlantic	-0.030*** (-6.157)	-0.003 (-0.574)	-0.027*** (-4.795)	-0.027*** (-4.277)	-0.055*** (-7.533)	-0.020** (-2.162)
Southern California	0.009* (1.926)	0.030*** (6.276)	0.003 (0.596)	0.011* (1.805)	-0.012* (-1.824)	-0.010 (-1.205)
Texas Triangle	-0.025*** (-5.620)	0.006 (1.260)	-0.018*** (-3.728)	-0.017*** (-3.185)	-0.041*** (-7.124)	-0.034*** (-5.066)
Not in megaregion	-0.010** (-2.542)	0.016*** (3.979)	-0.009** (-2.034)	-0.002 (-0.363)	-0.023*** (-4.688)	-0.021*** (-3.857)
Vehicle Share						
Arizona Sun Corridor	-0.007 (-0.838)	-0.043*** (-4.878)	-0.004 (-0.399)	-0.003 (-0.311)	0.044*** (3.280)	0.048** (2.178)
Cascadia	-0.017* (-1.696)	-0.065*** (-6.252)	-0.038*** (-3.124)	-0.048*** (-3.153)	-0.074*** (-4.087)	-0.029 (-1.165)
Florida	0.034*** (4.562)	-0.014* (-1.840)	0.008 (0.848)	0.041*** (3.803)	0.077*** (6.230)	0.092*** (4.736)
Front Range	0.002 (0.181)	-0.059*** (-4.564)	-0.029** (-1.963)	-0.018 (-1.066)	0.032 (1.544)	-0.006 (-0.232)
Great Lakes	0.025*** (3.830)	-0.026*** (-3.939)	-0.004 (-0.524)	0.011 (1.328)	0.045*** (4.970)	0.040*** (3.659)
Gulf Coast	0.005 (0.251)	0.002 (0.097)	-0.051** (-2.081)	-0.019 (-0.637)	0.005 (0.151)	0.034 (0.846)
Northeast	-0.037*** (-5.823)	-0.084*** (-13.017)	-0.079*** (-11.329)	-0.062*** (-7.931)	-0.027*** (-2.999)	-0.038*** (-3.362)
Northern California	-0.029*** (-4.032)	-0.077*** (-10.535)	-0.066*** (-8.249)	-0.040*** (-4.471)	-0.032*** (-3.429)	-0.015 (-1.292)
Piedmont Atlantic	0.047*** (6.792)	-0.009 (-1.303)	0.020*** (2.600)	0.051*** (5.797)	0.099*** (9.948)	0.069*** (5.437)
Southern California	0.000 (0.039)	-0.044*** (-6.438)	-0.008 (-1.126)	0.007 (0.898)	0.051*** (5.772)	0.044*** (3.951)
Texas Triangle	0.036*** (5.520)	-0.022*** (-3.404)	0.004 (0.580)	0.027*** (3.509)	0.066*** (8.205)	0.044*** (4.678)
Not in megaregion	0.022*** (3.674)	-0.028*** (-4.568)	-0.002 (-0.266)	0.014** (2.097)	0.057*** (7.925)	0.047*** (5.912)
Transit Share						
Arizona Sun Corridor	-0.010*** (-3.044)	0.011*** (3.029)	0.010** (2.349)	-0.005 (-1.082)	-0.013** (-2.316)	-0.010 (-1.032)
Cascadia	0.000 (0.039)	0.024*** (5.558)	0.017*** (3.211)	0.030*** (4.491)	0.022*** (2.730)	0.032*** (2.956)
Florida	-0.022*** (-7.404)	-0.002 (-0.562)	-0.004 (-0.955)	-0.023*** (-5.090)	-0.033*** (-6.208)	-0.038*** (-4.411)
Front Range	-0.001 (-0.272)	0.020*** (3.518)	0.022*** (3.479)	0.001 (0.103)	-0.004 (-0.393)	-0.005 (-0.408)
Great Lakes	-0.012*** (-4.944)	0.012*** (4.553)	0.015*** (5.274)	-0.004 (-1.143)	-0.010*** (-2.763)	-0.007* (-1.645)
Gulf Coast	-0.018** (-2.096)	-0.001 (-0.120)	0.009 (0.810)	0.006 (0.434)	-0.019 (-1.160)	-0.004 (-0.216)
Northeast	0.017*** (6.954)	0.039*** (15.652)	0.053*** (19.395)	0.035*** (11.182)	0.023*** (6.281)	0.047*** (9.828)
Northern California	-0.010*** (-3.572)	0.018*** (6.377)	0.021*** (6.591)	0.005 (1.327)	-0.002 (-0.409)	0.019*** (3.950)

Piedmont Atlantic	-0.019*** (-6.926)	0.006** (2.159)	0.004 (1.396)	-0.020*** (-5.534)	-0.036*** (-8.628)	-0.032*** (-5.774)
Southern California	-0.016*** (-6.180)	0.008*** (2.821)	0.003 (1.020)	-0.014*** (-4.280)	-0.030*** (-8.448)	-0.027*** (-5.859)
Texas Triangle	-0.016*** (-6.540)	0.011*** (4.335)	0.011*** (4.138)	-0.010*** (-3.305)	-0.018*** (-5.706)	-0.003 (-0.729)
Not in megaregion	-0.017*** (-7.633)	0.007*** (2.977)	0.008*** (3.302)	-0.012*** (-4.383)	-0.024*** (-8.543)	-0.013*** (-3.984)

Significant level: <0.01 (***), <0.05 (**), <0.1 (*)

Chapter 5. Discussions and Conclusions

This study expands the ongoing research on Millennials' travel preferences and choices in two aspects. First, the study constructs lifecycle distributions of the modal shares of individuals' daily travel using six NPTS/NHTS from 1977 to 2017. The unique dataset enables the analysis of inter- and intra-generational comparisons in continuous age ranges from 5 up to 71 years, which overcomes the limitations of many existing studies that examine generational travel only for a few selected age cohorts. By juxtaposing the modal share distributions across generations, the study reveals the varying trends of modal shares in different life stages between Millennials, Generation X, and Baby Boomers. Children from Millennials and Generation X show very different patterns of travel modal shares. Millennial children have low but rising shares of travel by walking/biking and transit as they grow from 5 to 12 years old. The trend for Generation X shows the opposite. Children's mobility depends largely on their parents, while their travel needs also influence the parents' travel decisions. Understanding the contrasting mode choice characteristics between Millennials and Generation X in their childhood warrants further research.

The trends of modal shares appear similar between the three generations during their teenage time; their transit and walk/bike shares decrease, and vehicle travel increases from age 13 to 19. After they turn 20, the modal shares of all generations display a relatively stable trend. An interesting observation shows that the relative levels of modal shares for the three generations shift to the opposite direction as they grow from teenage to young adult. Millennials have the lowest walk/bike share and the highest vehicle travel share among all generations in their childhood and early teenage time. During young adult age, Millennials' walk/bike share becomes the highest, whereas their vehicle travel share falls below other generations'.

The second aspect of this study's contributions lies in its exploration to the spatial heterogeneity of generational modal shares across megaregions. Most existing studies on Millennials' travel have dwelled at the national level, although a few used the state or census division identifiers to control for the influence of geographical variations. This study tests and confirms the influence of megaregional variations on modal shares across generations after controlling the effects of individual and household socioeconomic characteristics. Residents from specific generation subgroups living in Cascadia, Northeast, and Northern California have higher walk/bike and transit shares but lower vehicle shares than the average shares at the national level. Contrastingly, individuals from Piedmont Atlantic are much more auto-oriented. From the dynamic slope model specifications, the study quantifies the generational effects that moderate the influence of three selected predictors on modal share outcome (**Table 4.2**). The dynamic intercept model specifications help quantify the size of spatial (megaregional) and generational effects that modify the individual level of modal shares (**Table 4.3**).

The results of the study offer valuable information for transportation planning and policy making. The varying trends of modal shares over the age spectrum across generations highlight the importance of having cohort-tailored initiatives to achieve short- and long- term transportation objectives. Children and teenagers gain travel experience and develop travel preferences and attitudes that will affect their travel choice decisions in their adult life (Bush, 2003). Smart and Klein (Smart & Klein, 2018) report that individuals who enjoyed high-quality transit service during their young adulthood would be more likely to maintain the habit of taking transit in their later life. The contrasting patterns of children's modal shares observed in this study suggest an interesting topic for research: How different or similar the parent generations of Millennials and Generation X are in accommodating and cultivating their children's travel needs and habits? Research is also needed to understand how these early experiences affect their adulthood travel decisions.

Initiatives and programs orienting to the general public are important as well. The study observes the coincidence between the rise of walk/bike shares across all generations in different age groups and the nationwide campaign for active living around the turn of the new century. No direct evidence could be drawn from the NPTS/NHTS data on whether the active-living campaign drives up people's walk/bike shares in their daily travel. Yet it is reasonable to assume significant influences of the national efforts on people's rising walking/biking travel. In 2005, the federal legislation SAFETEA-LU authorized funding for SRTS that was initiated by CDC. Studies have shown increased walking and biking resulting from SRTS implementation as experienced by school children coming from the younger Millennials and the Generation Z (McDonald et al., 2014). Since the 1970s, there have been major expansions of highway and transit systems throughout the United States (Adler, 1993). The nation's transportation infrastructure has changed significantly, which should have influenced people's travel choices and decisions. Nevertheless, NHTS/NPTS do not include variables to consistently capture the changes in infrastructure supply. Future studies may collect the needed infrastructure data from other sources and combine them with NPTS/NHTS data to further improve understanding of travel behavioral differences between generations. Furthermore, as the new century witnesses the advancement in and adopted uses of information and communications technologies (ICTs), new mobility services are emerging, including e-Bikes, e-Scooter, and ride-hailing such as Lyft/Uber. It is essential to understand young generations' travel preferences and choices in the era of new mobility. However, in the data series of NHTS/NPTS, only the 2017 data provides variables capturing the usage of bike sharing, car sharing, and rideshare Apps (see an example of the study by Zhang and Zhang (Zhang & Zhang, 2018)). Data on toll payments are also reported inconsistently across NPTS/NHTS. These data constraints limit cross-generation comparisons, suggesting areas for improvements in future NHTS.

The quantification of megaregional and generational variations on modal shares as shown in **Table 4.2** and **Table 4.3** provides much needed empirical knowledge for transportation planning, for example, modal split analysis and modeling at the level between states and metropolitan areas. Conventionally, transportation planning is carried out by metropolitan planning organizations (MPOs) at the regional level and by state DOTs at the state level. MPOs and state DOTs have accumulated relatively rich knowledge and data. Growingly, transportation challenges such as travel demand growth, congestion, and transportation emissions are crossing metropolitan or state boundaries. There have been calls for collaborative cross-jurisdiction transportation planning and policy-making (Federal Highway Administration, 2018). Some states have started efforts for inter-MPO collaborations. For example, the Capital Area MPO in the Austin, TX area and the Alamo Area MPO in the San Antonio, TX conducted the Capital-Alamo Connections study to develop strategies for mobility improvement in the greater Austin-San Antonio region (Texas Department of Transportation, 2019). Nevertheless, transportation planning at the megaregional scale beyond the scope of individual MPOs faces major challenges; one of them is the lack of data and empirical knowledge (National Academies of Sciences, Engineering, and Medicine, 2016). This study provides a preliminary set of empirical knowledge from national surveys to address the challenges.

To conclude, generational shifts in travel preferences and choices exist as evident by the patterns of modal shares across Millennials, Generation X, and Baby Boomers over different life stages. Public policies and planning efforts should foster the trending preferences exhibited with the young generations towards sustainable travel by walking, biking, and transit.

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