

## **AN INVESTIGATION OF HETEROGENEITY IN VEHICLE OWNERSHIP AND USAGE FOR THE MILLENNIAL GENERATION**

### **Patrícia S. Lavieri**

The University of Texas at Austin  
Department of Civil, Architectural and Environmental Engineering  
301 E. Dean Keeton St. Stop C1761, Austin, TX 78712, USA  
Tel: 512-471-4535; Email: [lavieri@utexas.edu](mailto:lavieri@utexas.edu)

### **Venu M. Garikapati**

Arizona State University  
School of Sustainable Engineering and the Built Environment  
660 S. College Avenue, Tempe, AZ 85281, USA  
Tel: 480-522-8067; Email: [venu.garikapati@asu.edu](mailto:venu.garikapati@asu.edu)

### **Chandra R. Bhat (corresponding author)**

The University of Texas at Austin  
Department of Civil, Architectural and Environmental Engineering  
301 E. Dean Keeton St. Stop C1761, Austin, TX 78712, USA  
Tel: 512-471-4535; Email: [bhat@mail.utexas.edu](mailto:bhat@mail.utexas.edu)  
and  
The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

### **Ram M. Pendyala**

Arizona State University  
School of Sustainable Engineering and the Built Environment  
660 S. College Avenue, Tempe, AZ 85281, USA  
Tel: 480-727-4587; Email: [ram.pendyala@asu.edu](mailto:ram.pendyala@asu.edu)

## **ABSTRACT**

This paper explores differences in activity-travel behavior within the millennial generation with a view to better understand how their choices might shape transportation systems of the future. Through the estimation of a Generalized Heterogeneous Data Model on a special millennial mobility attitudes survey data set, this study investigates heterogeneity among millennials with respect to their driver's license holding status, vehicle ownership, and commute mode choice. After accounting for self-selection effects, age, parenting status, and location of residence have a substantial and statistically significant influence on auto-oriented mobility choices. Millennials seem to become more auto-oriented as they age and gain economic resources. Parenthood is associated with an increase in driver's license holding and personal vehicle ownership; however, in general, it does not seem to have a direct impact on commute mode choice. For all types of millennials, mode choice seems to be strongly related with residential location. Thus, the development of a well-connected public transit system and dense, mixed land-use are still the key ingredients to reducing car commute. Planning professionals should explore ways to retain millennials in the city core so that their sustainable transportation mode use patterns can be preserved into the future.

*Keywords:* behavioral heterogeneity, millennial generation, travel behavior, vehicle ownership, commute mode choice, driver's license holding, GHDM, latent variables.

## 1 INTRODUCTION

The millennial generation (comprising those born between 1980 and 2000) recently became the largest population segment in the United States (1). Due to the size and influence of the millennial generation, considerable attention is being paid to this generation's habits, consumer choices, and mobility patterns. A number of papers and reports have documented the differences in travel and lifestyle choices and preferences between different generations using a variety of surveys, aggregate statistics, and cohort analysis techniques. Millennials are said to be driving less, traveling fewer miles, obtaining their driver's licenses later, and using more public transit and non-motorized modes of transportation (2). However, skeptics believe that these observed effects will not necessarily persist over time as the behavioral traits exhibited by millennials may be a result of circumstantial economic conditions and the consequent delayed achievement of various adult lifecycle milestones (such as marriage, having children, and entering the labor force). Essentially, while some studies note a significant difference between millennials and the young adults of previous generations (3, 4), others assert that the societal changes at play are affecting the behaviors of all age groups in similar ways or that the changes will not last as this generation ages (5, 6) and experiences the more mature lifecycle milestones of adulthood.

What most of the above studies fail to acknowledge is that there is likely to be significant heterogeneity among millennials since this generation broadly comprises individuals born between 1980 and 2000. Among studies that investigate heterogeneity within the millennial generation, Garikapati et al. (6) find that younger millennials are quite different from older millennials even after controlling for age effects. It appears that older millennials show some of the traits of Generation X, the generation that just preceded the millennials while younger millennials show a greater difference relative to Generation X. Ralph (7) performs a latent class analysis to investigate millennials' travel patterns and identifies four distinct traveler types among this generation: individuals that travel almost exclusively by automobile, individuals that travel (drive) long distances, individuals that use a mix of modes (multimodal), and individuals that are car-less and make very few trips. Key sociodemographic traits, such as being younger, single, and living in dense urban areas, are reported to be associated with being multimodal or car-less. Garikapati et al. (6) and Ralph (7) show that the lack of consensus on whether the millennial generation is truly different from previous generations is probably a consequence of aggregating different individuals into a single generation and ignoring many possible sources of behavioral heterogeneity.

The current study contributes to the investigation of heterogeneity among the millennial generation by analyzing three key dimensions of interest in the context of sustainable travel behavior: driver's license holding, vehicle ownership, and commute mode choice. All of these variables capture the auto-oriented mobility proclivity of an individual. Those who are more auto-oriented are likely to have a driver's license, own more vehicles, and use the car for commuting to and from work or school. In an effort to better understand millennial choices in relation to auto-oriented mobility patterns, this paper presents a model system capable of accounting for the influence of latent constructs reflecting mobility and lifestyle preferences as well as attitudes towards the environment. These latent constructs are combined with a number of exogenous variables to explain millennial travel choices. The model incorporates a gamut of explanatory variables; however, two variables of special interest to this research effort are geographic residential location and parenting status. Variables representing the geographic location of residence are included in the model specification to determine the extent to which millennial travel choices may be attributed to geographic differences as opposed to fundamental differences in mobility preferences within the cohort. For example, millennials residing in larger dense cities of

the East Coast may have very different attitudes and preferences than those residing in the less dense and newer cities of the West. Thus, the focus on geographic location makes it possible to test the hypothesis that behaviors that are said to be inherent to the millennial generation (such as multi-modality and lower levels of vehicle ownership and use) are largely true in well-developed dense cities where transit and non-motorized modes of transportation offer a high level of service and access to destinations. The model system also explicitly considers the parental status of the individual in modeling choice of commute mode, vehicle ownership, and driver's license acquisition. Parental status may be considered a measure of transition into adulthood. In the absence of longitudinal data sets, comparing mobility choices of millennial parents against those of non-parents could help determine the extent to which delayed achievement of adult lifecycle milestones may be contributing to heterogeneity in millennial vehicle ownership and usage.

The data for this study is derived from the "Who's on Board 2014 Mobility Attitudes Survey" which covers cities across the United States (8). A simultaneous equations model is estimated using the Generalized Heterogeneous Data Model (GHDM) approach proposed by Bhat (9). This approach accounts for latent constructs and allows the joint estimation of a mix of ordinal, count and nominal dependent variables. The joint estimation of driver's license acquisition, vehicle ownership, and commute mode choice is intuitive due to the clear relationship among these choice dimensions and because unobserved factors that are likely to affect one of these choices are also likely to affect the other choices (for example, economic circumstances may delay both the choice to get a license and purchase a vehicle). The use of psychological latent constructs enables controlling for self-selection effects.

The remainder of this paper is organized as follows. The next section describes the behavioral framework. The third section describes the data set used in the modeling exercise. The fourth section presents model estimation results, while the fifth section offers concluding thoughts and policy recommendations.

## **2 BEHAVIORAL FRAMEWORK**

The model developed in this paper jointly analyzes three key mobility choices of millennials, including driver's license holding status, vehicle ownership, and commute mode choice. Vehicle ownership refers to individual vehicle ownership (i.e., whether the individual has a dedicated vehicle as opposed to simply having access to a household vehicle) while commute mode choice considers three possible alternatives—car, transit, and non-motorized modes. In modeling commute mode choice, the modeling methodology accounts for the variability in choice set across individuals. Not everyone may have car or transit available and this fact is taken into consideration in the construction of the choice set. Everybody is assumed to have access to non-motorized modes of transportation.

To model these three choice variables, a behavioral framework that integrates three latent attitudinal constructs (pro-environment attitude, pro-transit attitude and pro-car attitude) and a latent lifestyle construct (technology dependency) is developed. The distinction between the two types of latent constructs is motivated by the types of variables used as indicators. The latent attitudinal constructs have attitudinal variables as indicators, while the latent lifestyle construct uses variables describing observed behavior (such as number of tech devices owned by the individual) as indicators. The use of latent constructs is essential to capture unobserved self-selection effects underlying choice decisions and identify differences in mobility choice proclivity within the millennial generation. The form of the latent constructs was determined based on existing literature and the variables/indicators that were available in the data set. The literature

suggests that attitudinal factors such as pro-car, pro-transit, and pro-environment are key latent variables that have a significant impact on mobility choices exercised by people (10-12). The tech-dependency construct was added to this set of latent variables to reflect the impact of technology on mobility choices (especially for the younger generation which is considered more tech-oriented). Exploratory analysis of the data coupled with intuitive reasoning helped identify the indicators that should be associated with each of the four latent factors.

Figure 1 presents the conceptual framework for the model system developed in this paper. For the sake of brevity, the figure does not show all of the specific indicators that describe the latent factors, but they are described in the next section. The simultaneous equations model system depicted in Figure 1 captures self-selection effects arising from latent attitudes and lifestyles, and reflects the simultaneity in decision-making as individuals choose a bundle of choice alternatives consistent with their lifestyle preferences. Thus, those who have car-oriented attitudes may choose to get a driver's license, buy a car, and commute by car *together*, thus exercising a bundle of choices jointly. Common unobserved factors, if any, that simultaneously affect the choices under investigation are also accommodated in the behavioral framework through error correlations.

The model system is formulated and estimated using the GHDM. The GHDM comprises a latent variable structural equation model, and a measurement model that links the latent variables and exogenous variables to a set of different types of choice outcomes. This approach accommodates a mix of dependent variable types allowing the use of ordinal and count variables as indicators for the latent variables and jointly estimating multiple discrete choice outcomes within a single model framework. The approach uses a multinomial probit kernel for the discrete (nominal, binary, and ordinal) outcomes and explains the covariance relationship among a large set of mixed data outcomes through a much smaller number of unobservable latent factors. Details regarding the model formulation and sufficiency conditions for parameter identification are omitted in the interest of brevity and can be found in Bhat (9).

### 3 DATA

The data used in this study is derived from the "Who's on Board 2014 Mobility Attitudes Survey." The objective of the survey was to identify differences in attitudes and behaviors in the U.S. population with respect to public transportation and neighborhood residential location choice. The online survey was administered in 46 metropolitan statistical areas (MSA) covering the full geographical extent of the country. A total of 11,842 individuals responded to the survey. The cities where the survey was administered were divided into transit-deficient, transit-progressive, and transit-rich cities depending on the maturity and level of service of their transit systems. The more traditional transit-oriented cities that have a robust transportation infrastructure in place were defined as transit-rich cities (New York, Chicago, Washington DC, Philadelphia, Boston, and San Francisco). All three city categories had a similar number of respondents in the survey sample. The subsample used for analysis in this study is comprised of 3,309 individuals between 18 and 33 years of age who commute to and from work or school.

Among the three key choice variables of interest, both personal vehicle ownership and driver's license holding were asked directly in the survey. The third major choice variable is commute mode choice. In the survey, individuals were asked to report the frequency of use of each mode for commuting (there were eight options: car, bus, commuter rail, subway, walk/bike, carsharing, taxi, and carpooling). The chosen mode was taken to be the mode that was most frequently used by the individual. Three specific mode choice categories were defined for this study:

- Car, which included car, taxi, car-sharing, and carpooling
- Transit, which included bus, commuter rail, and subway
- Walk/Bike

In addition to these three choice variables that describe the extent to which millennials are auto-oriented with respect to their mobility choices, a number of indicators that represent attitudes, perceptions, and technology use are used to construct four latent factors. The attitudinal and lifestyle factors and the indicators that represent them are defined below.

- Technology Dependency: One ordinal indicator and two count indicators were used to represent technology dependency:
  - It is important for me to have access to communication technology (cellular, wifi, etc.) throughout the day
    - Five-point Likert scale, measured from “strongly disagree” to “strongly agree”
  - Number of tech devices owned by the individual
    - 0 to 4 devices (smartphone, GPS, personal computer/laptop, and tablet)
  - Number of activities undertaken using information and communication technology (ICT)
    - Takes a value of 0 to 7 depending on the activities among those listed below that the respondent indicated he or she pursued using ICT
      - Driving directions/navigation
      - Transit directions/navigation
      - Real-time traffic information
      - Real-time transit information
      - Video chat
      - Social networking
      - Read/watch the news
- Pro-car Attitude: Three ordinal indicators were used to capture a pro-car attitude. A three-level Likert scale (disagree, neutral, agree) is used to represent the degree of agreement with the various indicator statements. The original five-point Likert scale was collapsed into a three-point Likert scale in view of the small sample sizes in some extreme categories.
  - I need to drive my car to get where I need to go
  - I love the freedom and independence I get from owning one or more cars
  - When making a trip, I prefer to have the flexibility to use a car in case my plans change
- Pro-transit Attitude: This latent attitude is represented by four transit-related attitudinal variables. All indicators are ordinal and measured on a five-point Likert scale indicating the level of agreement (strongly disagree to strongly agree) or level of importance (very unimportant to very important) of each statement.
  - Riding transit is less stressful than driving on congested highways
  - I feel safe when riding public transportation
  - I like the idea of doing something good for the environment when I ride transit
  - Importance of proximity of public transportation when choosing residential location
- Pro-environment Attitude: This latent construct is based on three attitudinal indicators measured on a five-point Likert scale (strongly disagree to strongly agree).
  - I like the idea of doing something good for the environment when I ride transit

- If everyone worked together, we could improve the environment and future for the earth
- I would switch to a different mode of transportation if it would improve the air quality

In the interest of brevity, a detailed tabulation of sample statistics is not furnished within this paper but is available in an online supplement at <http://www.cae.utexas.edu/prof/bhat/ABSTRACTS/Millennial/OnlineSupplement.pdf>. Given the nature of the survey sample, it is quite suitable to examine factors affecting millennial mobility choices. When examining the indicators of pro-car attitude, it was interesting to find that millennials, as a whole, exhibit a pro-car attitude. For example, 68.7% of respondents indicated that they needed to drive their car to get where they need to go; 78.3% indicated that they loved the freedom and independence that owning a car provides; and 75.3% preferred to have the flexibility to use a car in case plans change. Respondents within the sample also seemed quite environmentally conscious; for example, 56.4% liked the idea of doing good for the environment when they ride transit; 42.5% agreed or strongly agreed with the statement that they would switch to a different mode of transportation if it would improve the air quality.

In terms of socio-economic characteristics, the results indicate that 17.7% are 18–20 years old, 26.8% are 21–24 years old, 46.1% are 25–29 years old, and 9.4% are 30–33 years old. About 46% of the sample is comprised of males, 64.5% commute by car, 22.8% commute by transit, and 12.7% commute by bicycle or walk. Also, 79% own a personal vehicle, which reflects a high level of car ownership for an exclusively millennial sample. As expected, a majority (62%) are single, and only 18.3% are parents. While 24.4% are students, 58.4% are employed full-time, and 17.2% are employed part-time. One in five live in transit-rich cities, 40% live in transit-progressive cities, and the remainder live in transit deficient cities. The sample exhibits a high level of education with 36% having a Bachelor's degree and 12.2% having a graduate degree. A large portion of the sample is comprised of renters (45.5%). Just about one-third own their homes and 21.2% live with their parents/family. Technology is embraced by the sample of millennials as evidenced by an 89.4% smartphone ownership rate. In terms of residential location choice, 37.5% reside in urban areas (downtown or central mixed-use and residential areas), 47.5% reside in suburban areas, and the remainder reside in small towns or rural areas (all MSAs contain observations from the four types of residential location). For modeling purposes, we collapsed the residential location variable in two categories - urban and non-urban (which encompasses suburban, small town, and rural areas).

#### **4 MODEL ESTIMATION RESULTS**

This section presents model goodness-of-fit measures and estimation results. In terms of the goodness-of-fit, the GHDM model performance may be compared to one that assumes independence across the endogenous choice outcomes toward the right of Figure 1. To do so, we estimated an independent heterogeneous data model (IHDM) in which we included the determinants of the latent constructs as explanatory variables. This is an independent model because the error term correlations across the dimensions are ignored, but the best specification of the explanatory variables is considered. The composite marginal likelihoods of the GHDM and IHDM models came out to be -741,014.0 and -744,233.8, respectively, showing the superior performance of the GHDM. The two models can also be compared through a non-nested adjusted likelihood ratio test which provides the probability that the difference in the likelihood ratio indices of the two models could have occurred by chance. A small value of the probability of chance

occurrence indicates that the difference is statistically significant and that the model with the higher value of adjusted likelihood ratio index is to be preferred. Details on the calculation of this test can be found in Bhat (13). The GHDM shows a better goodness-of-fit on the basis of the predictive likelihood values and the predictive adjusted likelihood ratio indices (Table 1). The non-nested likelihood ratio statistic also indicates the superior performance of the GHDM. In addition to the statistical test, we also examined the performance of the GHDM by (1) computing an “average probability of correct prediction” measure at the disaggregated level and (2) comparing the actual versus GHDM-predicted sample shares at the aggregate level. To conserve on space, we present only the results for the mode choice dimension of the model system (which depends on the driver’s license choice and vehicle ownership choice model components). The disaggregate measure (please see the top portion of Table 1) is found to be 64.8%. At the aggregate level, the predicted shares are computed by drawing 500 samples of 3,309 observations from a multivariate normal distribution and averaging the predictions. The absolute percentage bias values in the predicted shares are quite small, suggesting that the model is able to recover overall mode shares quite well. Overall, the model is found to offer an acceptable goodness-of-fit as evidenced by this assessment.

The model results are discussed next, separately for the structural equation component and the measurement equation component.

#### **4.1 Structural Equation Results**

The estimation results for the structural equation component of the model are presented in the bottom half of Table 1. The structural equation model relates a set of exogenous variables to the four latent constructs considered in this paper. In the case of technology dependency, the results indicate that higher levels of education contribute to higher levels of tech-dependency. This result is consistent with findings from a number of studies in the ICT use literature (14, 15). Living in a transit-rich city is also associated with a higher level of tech-dependency. In general, traditional cities are major hubs of innovation and technology and it would be expected that inhabitants of such cities would be more technology-oriented.

In terms of pro-car attitude, it is found that those who are in the youngest age group (18–20 years) show a lower level of this latent factor. In general, these individuals are likely to be students, are not likely to have the income or the need for a car, and have not yet experienced car ownership to a degree that makes them dependent on it, a finding consistent with that reported by McDonald (2). Parents are likely to express a greater pro-car attitude than non-parents, a finding that is consistent with expectations. Parents need the flexibility afforded by the personal automobile to chauffeur their kids in addition to fulfilling their own travel needs, and hence vehicle ownership is higher in households with children (16, 17). It is also found that a higher level of education is associated with a greater pro-car attitude. Those with a higher level of education may have higher incomes, and pursue more activities (17), creating a greater level of dependence on the personal automobile to accomplish various activities efficiently. As expected, those living in traditional (transit-rich) cities are less likely to be pro-car.

A number of socio-economic variables influence the pro-transit attitude. Those with a graduate degree are more likely to be pro-transit. Males are likely to have more pro-transit attitudes, a finding consistent with that reported by Habib et al (18). The youngest millennials (18–20 years) are less pro-transit than older millennials. It is interesting to note that this group of young millennials is less car-oriented as well. It appears that the youngest millennials eschew motorized modes of transportation in general (both cars and transit) and favor non-motorized transportation modes such as walk and bicycle (which are modes commonly used by students) as reported by



Delbos and Currie (19). An alternate interpretation of this result could be that attitudes and perceptions of younger millennials are still evolving and therefore they do not exhibit clear preferences towards any specific mode. Race and ethnicity are also found to be determinants of a pro-transit attitude. Whites are less likely to express a pro-transit attitude, while Hispanics are more likely to be pro-transit. Both results are consistent with previous studies (13, 17) and are possibly explained by cultural and income differences between the respective population segments. Individuals living in traditional (transit-rich) cities are found to be more pro-transit than those in transit-progressive cities, and both of these groups are more pro-transit than individuals in transit-deficient cities.

The effects of variables on the pro-environment attitude factor shows that younger individuals between 18 and 24 years of age tend to be more sensitive to the environment. Males are less likely to be pro-environment, a finding consistent with that reported in the literature (20). Being a parent is associated with a higher level of sensitivity to the environment, possibly because parents are more cognizant of the consequences of environmental degradation for their children's health and future quality of life. Whites are less likely to express pro-environment attitudes, a finding that corroborates those reported earlier by Kalof et al. (21). They argue that Whites generally enjoy a greater innate sense of worth and ability to weather risk. Hence they do not perceive environmental deterioration as presenting a threat to them, thus reducing their proclivity towards being environmentally conscious.

Finally, the correlations among the latent constructs are provided at the end of Table 1. Tech-dependency and pro-environment attitudes are positively correlated, suggesting that individuals who are tech-dependent are also likely to be environmentally sensitive. Similarly, those who are pro-transit are likely to be pro-environment as well, a finding consistent with expectations. A finding that is somewhat surprising and not consistent with expectations is the positive correlation between pro-car and pro-environment attitudes. Although a negative correlation is expected, a positive (significant) correlation is obtained, suggesting that pro-environment individuals also appreciate the liberty and flexibility that a personal automobile provides. This result suggests that pro-environment attitudes are not necessarily associated with the adoption of environmentally sensitive travel choices, and that there might be additional unknown factors affecting these attitudes.

## 4.2 Measurement Equation Results

The measurement equation results include estimation results associated with the non-nominal variables as well as the nominal (discrete choice) variables.

The estimation results for the non-nominal variables are shown in Table 2. This table shows the loadings of latent variables on the ordinal and count indicators that are used to represent the latent attitudes and lifestyle preferences. As discussed earlier, the latent constructs are defined based on attitudinal statements or variables describing observed behavior, and hence it is expected that all loadings would be positive and significant. Those who are tech-dependent feel that they need continuous connectivity, own more ICT devices, and conduct more activities using ICT devices. Similarly, pro-car individuals believe more strongly that they need to drive their car to get where they need to go, love the freedom and independence associated with owning a car, and prefer to have flexibility of using a car when planning a trip. Similar positive associations are found in the case of ordinal indicators representing pro-transit and pro-environment attitudes.

As shown in the behavioral framework (Figure 1), the model estimated in this paper accounts for self-selection effects (through the four stochastic latent variables) that may otherwise manifest

themselves inappropriately as causal inter-relationships among the three choice outcomes of driver's license holding status, vehicle ownership, and commute mode choice. In this regard, the exogenous variables (e.g., socio-demographic variables) can affect the three choice variables both directly and indirectly (through a latent variable or through an endogenous variable). Interaction effects between key variables such as age, parenting status, geographic location (whether the individual lives in a transit-rich, progressive or deficient city), and residential location (urban and non-urban) are also included in the specifications of the three simultaneous choices. The presence of direct, indirect, and interaction effects in the same specification make it difficult to extract meaningful interpretations from the raw estimation coefficients. In this paper, we choose to address this issue head on by computing and examining the aggregate-level pseudo-elasticities of the variables of interest. These pseudo-elasticities (PEs) represent the percentage change in probability of an individual choosing a specific alternative over the others. The PEs are computed by drawing two sets of 500 samples of 3,309 observations from a multivariate normal distribution. In the first set, the variable of interest is set to zero (all the rest fixed) and in the second set the variable of interest is set to one (all the rest fixed). For each set, the predictions from the 500 choice occasions are averaged across all individuals to compute the shares. Then the shares of the two sets are subtracted and a percentage change is calculated. For example, to compare the overall effect of urban living versus non-urban living (regardless of other characteristics), all individuals were first "set" to be living in a non-urban area and the aggregate shares of the endogenous variables were computed. Next, all the individuals were "set" to be living in an urban area and corresponding shares were computed. The percentage change in aggregate shares are presented as the PEs in Table 3. Thus, the results indicate that urban dwellers are, on average, 4.2% less likely to own a personal vehicle relative to non-urban dwellers.

Table 3 focuses on the pseudo-elasticities of variables that are particularly important in characterizing heterogeneity among millennials: younger vs. older millennials, millennials living in urban areas vs. those living in non-urban (suburban, small towns, and rural areas), millennials living in traditional transit-rich cities (MSAs) vs. those living in other cities, and parents vs. non-parents in different geographic locations. Note that an extensive list of other exogenous variables (such as gender, race, income, education, home tenure status, employment status, etc.) was included in the model but, in the interest of brevity, is not discussed here. The complete model specification and the estimated coefficients can be found in an online supplement at <http://www.cae.utexas.edu/prof/bhat/ABSTRACTS/Millennial/OnlineSupplement.pdf>.

#### *4.2.1 Driver's License Holding Choice*

Results from the model of driver's license holding status show that the lifecycle stage of an individual (as proxied by age and parenthood in Table 3) is probably the most relevant determinant of driver's license holding status. For example, the first variable under the last row panel of the table shows that being a parent is associated with a 2.8% increase in the probability of having a license. Residential location of the individual is found to play an important role in driver's license holding status (even after accounting for self-selection effects). Living in an urban area is associated with a greater likelihood of not having a license. The pseudo-elasticities show that living in a traditional transit-rich city decreases the probability of having a license by 3.4%.

#### *4.2.2 Personal Vehicle Ownership Choice*

The model of vehicle ownership shows similar results as the license holding choice model. Variables describing a lifecycle stage prior to mature adulthood (young age, being a non-parent,

especially a young non-parent; see the top and bottom row panels of Table 3) and variables indicative of residing in high-density areas (middle row panel) are associated with a decrease in the likelihood of owning a personal vehicle. Living in an urban area seems to have a greater effect on reducing personal vehicle ownership than living in transit-rich MSAs in general. This result suggests that a good transit network is not as effective as densification for reducing vehicle ownership levels.

Finally, absorbed in the results of Table 3, but not shown in Table 3, personal vehicle ownership is positively associated with pro-car attitudes and negatively associated with pro-environment attitudes. A tech-dependent lifestyle is associated with a lower likelihood of having a personal vehicle. This effect may be a consequence of the use of technology to obtain real-time travel information for alternative modes as well as access to services like car-sharing and ride-sourcing.

#### 4.2.3 *Commute Mode Choice*

Younger millennials (less than 25 years old) are more likely than older millennials to choose non-motorized modes, but the effects of age on the choice between car and transit as a commute mode are less pronounced. Indeed, as noted earlier, the youngest millennials were found to be less car-oriented, less transit-oriented, and more environmentally sensitive, which is consistent with a lifestyle that involves the use of non-motorized transportation modes. As expected, living in urban areas increases the likelihood of using non-motorized modes of transportation (even after accounting for self-selection effects), presumably due to the greater access to destinations in such areas. Also, in transit-rich cities, urban residential location choice is associated with an increase in the likelihood of commuting by transit, a finding that is consistent with expectations. It is interesting to note that while parenthood presents a clear positive effect on driver's license holding and personal vehicle ownership, it does not necessarily increase the likelihood of car commute (see the first row under the last row panel). In general, parents living in urban areas and/or transit rich-cities are more likely to commute by transit than parents living in suburbs, small towns, and rural areas. In transit-rich cities, being a parent is associated with a transit share decrease of 26.2%. However, parents living in transit-rich cities are still more likely to use transit as a commute mode than parents and non-parents living in transit-progressive or deficient cities.

Lastly, and again not shown explicitly in Table 3, a pro-car attitude contributes to commuting by car and a pro-transit attitude is positively associated with commuting by transit. Being tech-dependent increases the likelihood of an individual choosing transit and non-motorized modes for commuting.

## 5 CONCLUSIONS AND RECOMMENDATIONS

There is much interest in understanding the consumption patterns and mobility choices of millennials as they become the majority of the population. In comparison to prior generations, millennials are less likely to own and use cars, and more likely to travel fewer miles. However, millennial travel patterns have mostly been studied as a 'single group' behavior, without explicitly considering the heterogeneity that might be present within this cohort. This paper models millennial mobility choices with a focus on car-related travel choices (driver's license holding status, vehicle ownership, and commute mode choice). In particular, we sought to identify heterogeneity patterns within the millennial generation, while explicitly accounting for latent attitudinal and lifestyle factors (pro-environment attitude, pro-transit attitude, pro-car attitude, and technology dependency).

Our estimation results show that millennials exhibit considerable heterogeneity in behavior. However, also observed was that, despite being environmentally conscious, the majority of millennials still exhibit a proclivity towards being pro-car. These results suggest that personal automobiles are still seen as the straightforward option associated with freedom and flexibility, and that pro-environment attitudes do not necessarily result in the adoption of environmentally sensitive travel choices. Notwithstanding this observation, younger millennials (less than 25 years of age), both with and without children, are found to be more likely than older millennials to use non-motorized modes of transportation, not have a driver's license, and eschew car ownership for the time being.

Age and location of residence have substantial and statistically significant influences on auto-oriented mobility choices. Millennials seem to become more auto-oriented as they age and gain economic resources. Parenthood is clearly associated with an increase in driver's license holding and personal vehicle ownership; however, in general, it does not seem to have a direct impact on commute mode choice. Parenthood in transit-rich cities is associated with a decrease in transit-based commute; however, a parent living in a transit-rich city is still far more likely to commute by transit than a parent or a non-parent living in a transit-progressive or transit-deficient city. Results also show that land-use density can significantly contribute to the decision to opt out of vehicle ownership and use. Thus, the development of a well-connected public transit system and dense, mixed land-use are the still key ingredients to reducing car commute. It is inevitable that millennials will age and potentially gain economic resources; therefore, planning professionals should explore ways to retain millennials in the city core so that their sustainable transportation mode use patterns can be preserved into the future. In particular, our results clearly indicate a reduction in the use of non-motorized modes with age; however, if a well-developed transit network is available, users may switch from non-motorized modes to transit instead of car. Besides, mixed-use developments where millennials can work, play, and shop within short distances could help foster the continued use of non-motorized modes of transportation.

Technology use is another key factor associated with the choice of alternative modes of transportation. Individuals who are more technology-dependent exhibit lower levels of vehicle ownership and usage, and higher levels of non-motorized mode and transit use for commuting. This is evidence that well informed and connected individuals are better able to access and use alternative modes of transportation. Increasing the availability of real-time travel information through ICT, as well as developing innovative ICT-based transportation service solutions, may help prolong the sustainable travel patterns exhibited by the millennial generation in early adulthood.

A key limitation of the current study stems from the use of a cross-sectional data set, which precludes the possibility of comparing mobility choices across generations while controlling for age effects. The availability of longitudinal data would allow for such comparisons and also help explain changes in attitudes/beliefs over time. Exploring the question of whether current attitudes can predict millennial travel behavior in the future is a fruitful direction for additional research.

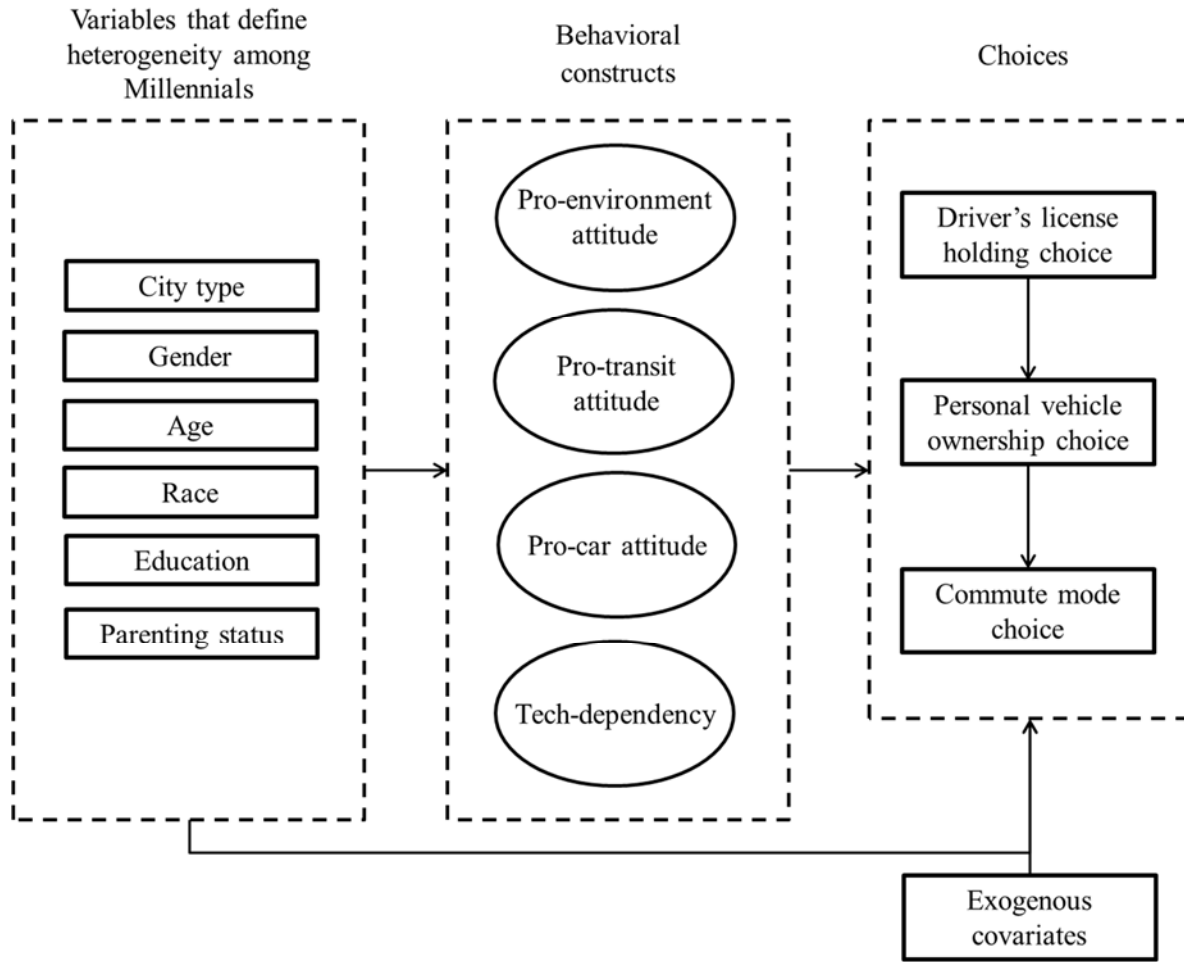
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**FIGURE 1 Behavioral framework.**

**TABLE 1 Model Goodness-of-Fit and Structural Equation Estimation Results**

Goodness-of-fit								
Summary Statistics			GHDM		IHDM			
Log-likelihood at constants			-9,792.8					
Predictive log-likelihood at convergence			-7,479.4		-8,211.5			
Number of parameters (not including constants)			119		164			
Number of observations			3309		3309			
Predictive adjusted likelihood ratio test			0.224		0.145			
Non-nested adjusted likelihood ratio test			$\Phi[-38.85] \ll 0.0001$					
			Car		Transit		Non-motorized	
Average probability of correct prediction for each alternative			76.0%		37.9%		26.0%	
Actual sample shares			75.7%		13.8%		10.5%	
Predicted shares			75.6%		14.1%		10.3%	
Absolute percentage bias			0.13%		2.17%		1.90%	
Overall probability of correct prediction			64.8%					
Structural Equation Component								
Variable	Tech-dependency		Pro-car		Pro-transit		Pro-environment	
	Coef	(t-stat)	Coef	(t-stat)	Coef	(t-stat)	Coef	(t-stat)
<i>Education (base: &lt; Bachelor's degree)</i>								
Bachelor's degree	2.692	(2.31)	0.253	(6.14)	--	--	--	--
Graduate degree	2.692	(2.31)	0.253	(6.14)	0.116	(1.79)	--	--
<i>Age (base: 30-33 years old)</i>								
18 to 20 years old	--	--	-0.263	(-3.82)	-0.136	(-2.07)	0.060	(1.53)
21 to 24 years old	--	--	--	--	--	--	0.060	(1.53)
25 to 29 years old	--	--	--	--	--	--	--	--
<i>Male (base: female)</i>								
Parent (base: no kids)	--	--	0.285	(4.17)	--	--	0.062	(1.52)
<i>White (Base: Asian, Black, Native Am)</i>								
Hispanic (base: non-Hispanic)	--	--	--	--	0.368	(5.58)	0.191	(3.26)
<i>City type (base: transit deficient)</i>								
Transit-Progressive	--	--	--	--	0.309	(5.66)	--	--
Transit-Rich	1.015	(1.83)	-0.252	(-6.22)	0.574	(7.77)	--	--
Latent variables correlations					Coefficient		(t-stat)	
Tech-dependency and pro-environment					0.354		(2.22)	
Pro-car and pro-environment					0.382		(9.25)	
Pro-transit and pro-environment					0.724		(15.90)	

(--) not statistically significant and therefore removed from the model



**TABLE 2 Impact of Latent Variables on Non-nominal Dependent Variables and Correlations Among Latent Constructs**

Impact of Latent Variable on Non-nominal Indicators					
Latent variable	Indicators	Const.	(t-stat)	Coef.	(t-stat)
	<b>Ordinal</b>				
Pro-car attitude	I need to drive my car to get where I need to go	1.531	(35.81)	0.711	(29.93)
	I love the freedom and independence I get from owning one or more cars	2.396	(37.06)	1.165	(50.16)
	When making a trip, I prefer to have the flexibility to use a car in case my plans change	2.159	(39.56)	0.868	(40.13)
Pro-transit	Riding transit is less stressful than driving on congested highways	1.925	(25.35)	0.872	(33.50)
	I feel safe when riding public transportation.	2.112	(29.45)	0.820	(21.67)
	Proximity to public transportation is important when choosing household location	1.171	(21.14)	0.630	(22.87)
	I like the idea of doing something good for the environment when I ride transit	3.241	(29.67)	0.137	(2.66)
Pro-Environment	I like the idea of doing something good for the environment when I ride transit	3.241	(29.67)	1.075	(15.41)
	If everyone works together, we could improve the environment and future for the earth	2.838	(29.20)	0.610	(31.14)
	I would switch to a different form of transportation if it would improve air quality	2.954	(33.65)	1.079	(47.54)
Tech-dependency	Importance of having access to ICT throughout the day	2.237	(23.53)	0.042	(1.88)
	<b>Count</b>				
Tech-dependency	Number of ICT devices that the individual owns	1.461	(37.94)	0.114	(2.47)
	Number of activities conducted using ICT devices	0.927	(28.38)	0.094	(2.34)

**TABLE 3 Pseudo-elasticities for Age, Geographic and Parenting Effects on Driver's License Holding, Personal Vehicle Ownership and Commute Mode Choice**

	Driver's License		Personal Vehicle		Car Commute		Transit Commute		Non-motorized Commute	
	Coef.	(t-stat)	Coef.	(t-stat)	Coef.	(t-stat)	Coef.	(t-stat)	Coef.	(t-stat)
<i>Age Effects</i>										
Age 18 to 20 (base: $\geq 25$ years)	-7.3%	(-3.68)	-14.1%	(-8.09)	-6.8%	(-3.57)	-10.2%	(-2.33)	90.8%	(6.64)
Age 21 to 24 (base: $\geq 25$ years)	-0.5%	(-1.21)	-6.1%	(-7.42)	-4.1%	(-3.91)	-3.5%	(-2.08)	49.5%	(5.53)
Young parent (base: old parent)	-5.9%	(-3.71)	-21.9%	(-6.64)	-15.0%	(-4.55)	-5.8%	(-0.93)	169.6%	(7.11)
<i>Geographic and Land Use Effects</i>										
Urban (base: non-urban area)	-1.9%	(-0.86)	-4.2%	(-2.32)	-5.4%	(-4.54)	18.3%	(5.23)	19.2%	(2.47)
Transit-rich city (base: transit-progressive or deficient cities)	-3.4%	(-4.85)	-2.4%	(-3.52)	-11.5%	(-2.36)	84.3%	(5.02)	-10.0%	(-1.54)
Transit-rich city and urban (base: transit-progressive or deficient cities and urban)	-3.6%	(-4.63)	-2.5%	(-3.53)	-19.5%	(-2.92)	141.3%	(6.51)	-15.1%	(-2.32)
Urban and transit-rich city (base: non-urban area and transit-rich city)	-2.3%	(-0.85)	-4.4%	(-2.30)	-16.5%	(-4.19)	68.6%	(7.26)	7.8%	(1.02)
Parent in urban area (base: parent in non-urban area)	-1.6%	(-0.84)	-6.0%	(-3.34)	-7.7%	(-4.49)	40.5%	(7.93)	13.7%	(1.81)
Parent in transit-rich city (base: parent in transit-progressive or deficient cities)	-1.2%	(-3.79)	-0.4%	(-1.04)	-3.8%	(-2.10)	25.8%	(3.72)	-3.7%	(-1.14)
Parent in urban area in a transit-rich city (base: parent in urban area in progressive or deficient cities)	-3.0%	(-4.19)	-0.1%	(-0.07)	-22.7%	(-3.19)	159.0%	(6.76)	-19.2%	(-2.98)
Parent in urban area in a transit-rich city (base: parent in non-urban area in a transit-rich city)	-1.9%	(-0.85)	-5.8%	(-3.29)	-20.6%	(-4.25)	94.2%	(6.44)	1.0%	(0.12)
Parent in urban area in a traditional city (base: parent in non-urban area in progressive or deficient cities)	-4.5%	(-2.07)	-4.5%	(-2.36)	-25.3%	(-3.50)	175.2%	(6.53)	-2.1%	(-0.19)
<i>Parenting Effects</i>										
Parent (base: non-parent)	2.8%	(3.08)	2.8%	(2.29)	-0.3%	(1.24)	7.2%	(1.24)	-7.0%	(-2.73)
Young parent (base: young non-parent)	4.1%	(2.83)	6.5%	(2.71)	0.6%	(0.46)	5.2%	(0.81)	-4.9%	(-2.39)
Parent in transit-rich city (base: non-parent in traditional-city)	4.9%	(4.35)	7.4%	(5.55)	8.8%	(1.86)	-26.2%	(-4.77)	0.1%	(0.01)
Parent in transit-rich city (base: non-parent in non-traditional city)	1.5%	(1.64)	4.5%	(3.68)	-3.9%	(-2.02)	35.4%	(3.79)	-10.1%	(-2.65)