A Thesis

entitled

A Study of Travel Mode Choice Behavior of Women in the USA

by

Ahmad Ilderim Tokey

Submitted to the Graduate Faculty as partial fulfillment of the requirements for the

Master of Arts Degree in Geography and Planning

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The University of Toledo

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An Abstract of

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Non-Motorized Transportation (NMT), Public Transportation (PT), and Private Motorized Transportation (PMT) are three principal strands in the modal ecosystem. A large body of literature has underscored the gender gap in using these modes. However, there is a dearth of literature with an exclusive focus on women's mode choice using a broad array of variables and a wider timeframe. In response, this study attempts to fill the gap by finding the role of the factors affecting the mode choice of women in the USA. Further, it investigates how, or if, the factors' role has changed over time (from 2001 to 2017). This study uses National Household Travel Survey (NHTS) datasets from 2001, 2009, and 2017 surveys. Three multinomial logit models are estimated where odds of using NMT and PT are assessed against PMT under different conditions of independent variables. The factors investigated in this study include sociodemographic, household-related, trip-related, and built environment-related factors.

Results indicate that chances of using NMT are higher among elder, black, and employed women than their counterparts. Women with low family income, in a rented house, and with few vehicles in households are associated with higher odds of using NMT. The effect

of age and number of vehicles in a household on opting for PT is the same as that for NMT. Unlike NMT, white women and non-working women (e.g., homemakers, looking for a job) prefer PT more. To choose PT, the women from rented houses do not differ from women living in owned houses. Women in urban areas are more inclined to NMT and PT than PMT. This study also discusses the effect of different population density classes and educational qualifications. This research would help policymakers and urban planners to detect social groups where usage of sustainable transportation options is comparatively low. This study also urges them to arrange different promotional programs for more sustainable modes and help transportation network companies (e.g., transit companies, bike-share companies) improve accessibility and affordability.

I dedicate this thesis to my Nana and Nani from whom I garnered a lot inspiration to complete higher study.

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All credit and praise of this endeavor goes to Almighty Allah, without whose will nothing would be possible for me.

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

AU.....Australia

CN.....Canada

FHWA.....Federal Highway Administration

HH .....Household

ISU .....Iowa State University

NHTS .....National Household Travel Survey
NMT.....Non-Motorized Transportation

PMT .....Private Motorized Transportation
PT.....Public Transportation

RDD .....Random Digit Dial
RV .....Recreational Vehicle

SPSS.....Statistical Package for the Social Sciences
SUV.....Sport Utility Vehicle

US .....United States
USD.....United States Dollar

List of Symbols

$\pi(x)$.....Probability of choosing a mode given x
α .....Angle of incidence
β_0 .....Intercept
β_0 .....Coefficient
ln .....Natural logarithm
e .....Euler's number

Chapter One

Introduction

Background of the study

Over the world, Non-Motorized Transportation (NMT), Public Transportation (PT), and Private Motorized Transportation (PMT) are three dominant kinds of modes that create an image of a city or a community together with their different share. In order to achieve a sustainable transportation system, it is indispensable to rethink increasing active transportation usage in auto-dominant cities. (Fu and Farber 2017). Despite having a well-documented and publicized deleterious effect, motorized vehicles continue to proliferate in the USA (Paulssen et al., 2014). These dominant modes, which have been discussed for so long, gained much popularity for comparative studies in recent years.

To formulate policies centering on social equity and sustainability, having a wider understanding of the modal choices for vulnerable classes of society is essential. In response, there are substantial efforts made in recent literature to investigate the travel behavior of women. The gap of gender in travel behavior has been repronounced by researchers. For example, in the USA, females have a higher probability of commuting by walking than males (Tyler et al., 2016) and a lower probability of commuting by bike (Pucher et al., 2011). Some researchers studied the mode choice of car-deficient women (Scheiner and Holz-Rau, 2012), school-going females (Mandhani et al., 2021), and women's holiday travel (Li et al., 2016). Effect of life events (Scheiner, 2014), ecological norm (Matthies and Klöckner, 2002), bicycle facility (Rowangould and Tayarani, 2016),

etc., have also been studied. With the social changes in the USA, the factors affecting women's mode choice here should receive consistent attention from researchers.

Rationale of the study and Problem statement

In that context of the USA, the National Household Travel Survey (NHTS) made the path very smooth for transport researchers with its polished data that has a large sample size and richness in the variable. Researchers studied diversified issues regarding modal choices (Yang et al., 2011; Blumenberg and Pierce, 2016; Quinn, 2016, Konotu, 2019; Sharmin, 2019). In recent studies, an exclusive emphasis on unveiling factors affecting females' mode choice has not received much attention. The findings of these studies are sometimes confined in their local spatial context and temporal dimension. Also, due to the social changes, the roles of the factors may have been changed, which is also not investigated by many studies with a wider timeframe and richness in variables.

Objectives of the Study

General objective. To this end, this study attempts to fill the gap by finding the role of the factors affecting the mode choice of women in the USA.

Specific objective. In specific, this research seeks answer to the following two question.

1. What are the factors that affect the mode choice of women?
2. How, or if, the role of the factors is changed over time (from 2001 to 2017)?

The factors include in this study sociodemographic, household-related, trip-related, and built environment-related factors. In order to see the modal choices, this research mainly focuses on three kinds of dominant strands of modes stated above: NMT, PT, and PMT.

This study will be using NHTS datasets for 2001, 2009, and 2017. Evaluating the roles of the factors in these three years will help to understand the temporal dynamics of the association or effect of different factors.

Hypothesis of the Study

This study sets several hypotheses before conducting the analysis. Regarding the usage of NMT, it is hypothesized that younger, white, highly educated, and rich females use bicycles less than their respective counterparts. They also prefer PMT over it when the trip distance is long and many trip companions. Females, when coming from the rented household or households where the number of vehicles and drivers is low, their chance of using NMT increases. In highly dense and urban areas, the rate of cycling is higher than their counterparts. On the other hand, regarding PT usage, the effect of age is not clear; it can be parabolic and have a peak age group above and below which chance of using PT drops. White and highly educated women use transit less than the car. The effect of income is also ambiguous, like age. Higher trip length does not deter from using PT as it does for cycling. The effect of trip companions on transit usage is not clear.

Scopes and limitations of the Study

As stated above, this study analyzes the factors affecting the mode choice of women. Also, it uses NHTS datasets. The scope of this study is within only females and is not limited to any specific trip purposes, income classes, or urban areas. Also, this study is for the whole United States and does not represent any specific locality. It has some limitations as well. NHTS datasets do not disclose the geographical locations of the respondents. Therefore, any spatial dependence among the respondents' mode choices

cannot be accounted for. Further, there are limited options for built environment factors in the dataset. Many other built environment elements (e.g., land use, street density, commercial zoning, traffic volume), which were found influential by many studies, could not be included in this study.

Chapter Two

Review of Literature

Gender in mode choice study

While many social groups are being discussed in the sphere of transport equity, growing concern about gender and inequality has led to a visible proliferation of research (Queirós and da Costa, 2012). Gender has shaped social relations and mobility by producing gender variations in the choice, behavior, perceptions, and experience with mobility (Law 1999). From a wide variety of geography, literature has confirmed the different travel patterns of men and women (Rosenbloom 2004; Babinard and Scott 2009). Women's household responsibilities, time-use patterns, and work nature are quite different from **men**. This gap affects their ability to make trips on different day times (Hamilton et al., 2005). This variation is coupled with the distinct mode choice of this group, which is sometimes argued to be affected by women's economic power, social roles, preferences, and patriarchy (Scheiner and Holz-Rau; 2012). The result, however, varies greatly over the world. For example, while women use public transportation more than men in western and European cities, this mode is usually male-dominated in several growing cities in Asia (Zhao and Li, 2016; Adeel et al., 2016). Moreover, women's different preferences and needs towards different modes often involve them with the risk of economic exclusion (Dobbs 2005) or charge them for insecurity costs (Shadwell 2017), which also varies over different parts of the world.

Table 1 presents the key findings of several studies conducted over the world. These studies bring up the gendered differences in mode choice, inter-modal relationship, trip frequency, trip distance, attitude, and preferences. Notably, there is a strong presence of

geographical heterogeneity in their findings. Women, in general, prefer bicycle and PT more than men while men prefer automobile more than women. Interestingly, women's likelihood towards biking is less than men when they commute between home and university. Four campus-based study in the US have found this result. For job-related commuting, women in Canada prefer carpooling/public transit/park & ride less than men. A US study from San Francisco found a reverse finding that male prefer carpooling/shuttle more than female. Compared to male, likelihood to use bicycle for commuting is found more in Canada and less in Australia.

The mode choice can be related to other factors and that can have gendered difference as well. Females are more susceptible to the attributes of other modes while choosing her own mode than males. For the effect of having high income or owning a car, one can be pushed towards using a car. However, this push works in a less strong way for females. Males are less prone than females to use PT when they are more educated. On the other hand, higher age and higher education level appear to affect the likelihood of females to use bicycle negatively. Females are highly affected by commuting constraint (i.e., space-time constraint). They are willing to walk/bike, but beyond the walking, they opt for a car more than males.

The preferences and travel behaviors have also differed between these two groups. Females are usually concerned about safety more than males. They avoid longer bike commuting and prefer for safer bike infrastructures. While high trip frequency (for commuting) was observed for Chinese females when they use PT/NMT, auto-based grocery shopping was found in high frequency by American females.

Table 1

Summary of gendered difference in travelling

Study no.	Study area	Statements	Sign
	Mode choice (general)		
1	Suzhou, China	Likelihood to prefer bus	+
1	Suzhou, China	Likelihood to prefer car	-
1	Suzhou, China	Likelihood to prefer bicycle	+
2	Netherland	Likelihood to commute in auto	-
3	Guangzhou, China	likelihood of using PT	+
4	ISU	Likelihood to choose PT	+
	Mode choice (university commute)		
5	Baltimore college	likelihood to commute in bicycle	-
6	Univ. of Maryland	likelihood to commute in bicycle	-
4	ISU	likelihood to commute in bicycle	-
	Mode choice (job commute)		
8	Edmonton, CN	Likelihood to prefer carpooling/public transit	-
8	Edmonton, CN	likelihood to choose bicycle	+
9	Brisbane, AU	preference for car/taxi/PT	+
9	Brisbane, AU	likelihood to choose bicycle	-
10	San Francisco, US	preference for car-pooling or shuttle	+
	Different effects on mode choice		
1	Suzhou, China	effect of other mode	+
		effect of income and car ownership on car usage	-
		effect of higher education on PT usage	(+) ve
		effect of age and education on bike usage	(-) ve
11	Kunming, China	car usage beyond walking distance	+
		effect of commuting constraint	+
	Modal interaction		
12	Nanjing, China	ability to accept combined mode	+
12		acceptance of metro-based transfer	+
	Preference		
13	Germany	willingness to reduce car usage	+
14	San Francisco	avoidance to risky bicycling	+
5	Baltimore College	aversion towards longer commute in bicycle	+
16	Melbourne, AU	prefer to use bicycle routes than shared paths.	+

+ higher than male; — lower than males

1(Yang et al., 2013); 2 (Schwanen et al., 2004); 3 (He & Thøgersen, 2017); 4 (Zhou et al., 2018); 5 (Abasahl et al., 2018); 6 (Akar & Clifton, 2009); 8 (Nurul Habib et al., 2011); 9 (Kamruzzaman et al., 2015); 10 (Malokin et al., 2019); 11 (Ji et al., 2018); 12 (Liu et al., 2019); 13 (Matthies et al., 2002); 14 (Guo & He, 2021); 16 (Garrard et al., 2008)

Having discussed the gendered difference, it is necessary to emphasize the gendered equity issues and the transportation options of the least advantaged community. While discussing the modal availability or modal choice of women, different factors come into play, including sociodemographic, household, trip-related, and built environment-related factors. There are some other subjective, political, natural, and social factors as well.

Sociodemographic factors affecting mode choice

Researchers have built an understanding of different sociodemographic factors' role in choosing travel modes. These primarily include age, income, education, and race. Tyler et al. (2016) analyzed NHTS data of 2009 and found that younger women are associated with more walking/biking. Using the same dataset, Ugo Lachapelle (2015) concluded that there is an inverse relationship between age and transit usage for women. Income is another strong determinant for mode choice. Bhat and Sardesi (2006) conducted a web-based survey and found a negative relationship between income and NMT, PT (except rail), and shared vehicle usage. However, they did not find such a relationship for rail. Tyler et al. (2015) also found an association between lower income and higher usage of active transportation. They found that the lowest income group (0-24000 USD) has significantly higher odds of walking than the other higher-income groups. Ugo Lachapelle (2015) found a negative relationship between transit usage and income. Chia-Yuan Yu and Hsien-Chang Lin (2016) used the 2009 NHTS dataset and found that among transit users, lower-income people tend to walk as a first-mile transport more than the higher-income people. Pucher et al. (2011) analyzed 2001 and 2009 NHTS datasets and found the odd of using active transportation is higher for people with high school degrees than people more

educated than them. This finding is also factual for first-mile and last-mile trips (Yu and Lin, 2016). Race plays a vital role in determining mode usage. In general, Non-Hispanic white people are more likely to use bicycles in 2001 and 2017 (Buehler et al., 2020, Pucher et al., 2011). Tyler et al. (2016) also concluded with such findings using the 2009 NHTS dataset. However, Nehme et al. (2016), exclusively studying females with NHTS 2009 dataset, found that white females tend to use bicycles less than Hispanic, Black, and Asian females in 2009.

Household and trip-related factors affecting mode choice

Household characteristics are related to modal availability. Odd of driving alone increases when there are many motorized vehicles in households (Bhat and Sardesai, 2006). Lingqian Hu (2020) analyzed NHTS 2017 data and found a similar relationship. This author found that the odds of using automobiles for commuting increases when the vehicle per driver ratio is high. Using the same dataset, Buehler et al. (2020) found that the rate of using bicycles by a household with two cars is a tenth as high as a household without an automobile. Travel distance is a major attribute of travel behavior. Lingqian Hu (2020) did not find a difference in commuting distance between men and women in NHTS 2017 dataset. However, the commute distance is longer for Black and Hispanic than whites

Built environment related factors affecting mode choice

The built environment is a highly influential factor of travel behavior, trip frequency, mode choice, etc. (Cervero, 2002). The characteristics of a place and its density, diversity, and design, pronounced together as 3D, play a pivotal role in travel demand (Cervero and Kockelman, 1997). Population and employment density, job accessibility,

dissimilarity index, land use proportions, activity center mixture, street design, provision for pedestrian and cyclists, site design, etc. are commonly used measures of the built environment (Cervero and Kockelman, 1997; Ewing and Cervero, 2001; Ewing and Cervero, 2010). Studies have looked into the effects of the built environment on the mode choice of urban residents (Chen et al., 2008; Aziz et al., 2018), rural residents (Ao et al., 2020), school travels (Mitra et al., 2010; Broberg and Sarjala, 2015), and commuting trips (Pinjari et al., 2007).

Studies have indicated that population density is directly connected with travel. Nehme et al. (2016) analyzed 2009 NHTS data and concluded that people in higher density (e.g., 2000 person/mile2) uses bicycle more than people in lower density (e.g., 500 person/mile2). Buehler et al. (2020) also found similar findings with 2001 and 2017 data. In these years, a higher cycling rate is associated with greater population density. The least dense areas observed cycling as half as densest areas did. Ugo Lachapelle (2015) found a positive relationship between housing density and transit usage. On the other hand, walking duration reduces with population density when it is for first-mile or last-mile trips (Yu and Lin, 2016). Increased walking and biking are observed in urban areas compared to rural areas (Tyler et al., 2016; Pucher et al., 2011)

NHTS dataset in travel behavior study

Scholars tried to discover the mode-related dynamics from different angles. For example, Yang et al. (2011) used 2001 NHTS and discovered the effect of seasonal variation that leads to a choice of active transportation. Blumenberg and Pierce (2016) modeled the unimodal and multimodal trips with many other socio-demographic variables and residential density collected from 2009 NHTS. Work trips highly influence mode

choice and non-motorized transport (NMT); however, this is not the dominant mode in the USA. Despite that, many studies tried to capture the commuting behavior of cyclists in the USA. Using NHTS 2009 database, Quinn (2016) concluded that an increased odd of active commuting was associated with younger age, lower-income, urban-dwelling, and the highest and lowest education categories. While many studies focused on work trips, non-work traveling, what is mostly NMT famous for, did not gain that much popularity (Khan et al., 2014). Walking and bicycling, which are related to many important variables, are primarily used for social and recreational trips and trips to school (Pucher and Renne, 2003). The odds of using NMT for school trips increases with residences closer to schools, zero and low vehicle ownership, residing in areas with greater population density (Konotu, 2019; Sharmin, 2019). For shopping trips, the odds of using NMT are higher for people with no full-time job (Zhou and Wang, 2014).

Directions of the review

From the review of the factors affecting mode choice, it is clear that many of the factors are quite intuitive. Also, from data perspective, NHTS made the path very smooth for transport researchers with its polished data with large sample size and richness in the variable. Researchers have analyzed this dataset to come to a generalized conclusion for the whole country. Since this data is collected in eight years intervals, several variations of the effect of different factors can be observed due to social changes. The discussed studies mostly found evidence of age, income, education, number of vehicles, population density, and other factors affecting mode choice. Some of the studies have an exclusive section for women's mode choice. The rest of the current is based on the light of these

Chapter Three

Research Design and Methodology

Type of Research

This research is exploratory in nature. We will be exploring the factors that affects the modal choice of our target groups as well as how the factors varied across the time.

Sources of Data and Data Acquisition

Secondary Data Source. This study is conducted with the help of secondary data. The main database used in this study is the NHTS database. With its wide range of variables and the large sample size, this data is helping policymakers, academicians, and transportation professionals make informed decisions. We used the three latest databases published in 2001, 2009, and 2017 in this study. All the data can be downloaded from https://nhts.ornl.gov/ (for 2017) and https://nhts.ornl.gov/download.shtml (for 2009 and 2001).

Description of Secondary Data Source. Since 1969, Federal Highway Administration (FHWA) has been publishing the NHTS database by collecting personal travel data of the people of America. It carries information about travel in all the states and the District of Columbia. Data is collected directly from the household chosen by the stratified sampling method. This method, however, was followed for 2017 only, whereas in previous years, Random Digit Dial (RDD) telephone sampling method had been used.

This survey collects data of the trip made on the assigned travel date by the household members. Consequently, it collects data of the household, person, and vehicle. There are four files in this database: household, person, vehicle, and day trip. In the household file, the characteristics of each household are recorded. Information about the

vehicle(s) owned by that household is recorded in the vehicle file. Each member's personal information and trips made by each household member are recorded in the personal and day trip files, respectively. Thus, the day trip file has the most granular information (Westat, 2018). An overview of the major variable collected under each file is shown in Figure 1.

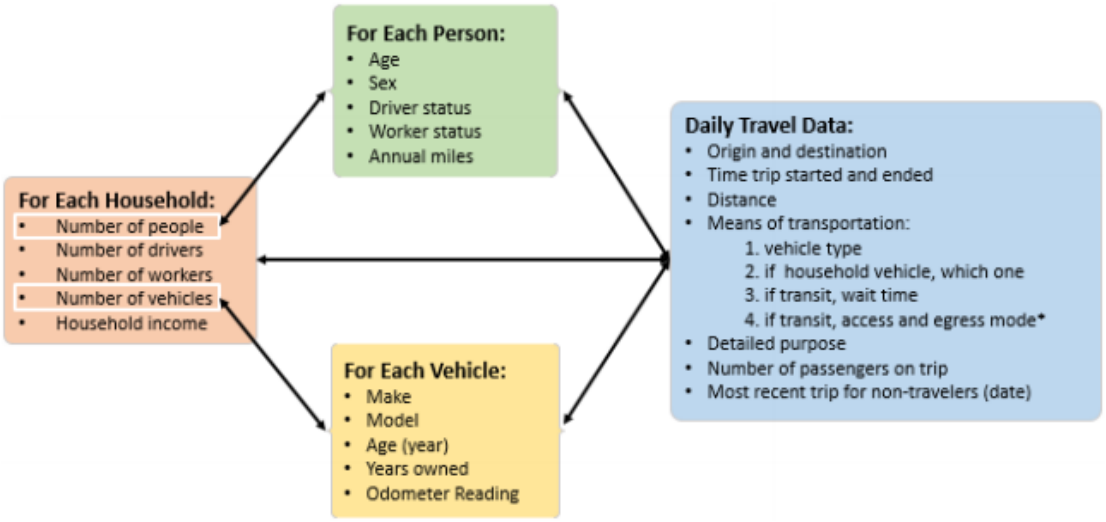

Figure 1. Schematic Diagram of 2017 NHTS Data Source: Figure 1-2 Schematic of 2017 NHTS Data, 2017 NHTS Data User Guide (p. 7)

Design of Research

Study Area and Target group. The study area of this study is the whole United States which contains 50 states and the District of Columbia. The data were first collected using the respective sampling method from every state and then attributed with a weight to overcome the problem of sampling bias, adjust the nonresponse problem, and, primarily, produce population-level estimates. All the respondents that mentioned their gender as female are the target group of this study.

Timeframe and the Unit of analysis. This study uses data collected in 2001, 2009, and 2017. For all these three years, trip data has been used as the unit of analysis. The trip

maker and his household information were joined with trip data from the person and household files.

Data processing. As variables from multiple files, mostly from person and day trip files, are used, data were merged based on household ID, person ID, and trip ID. As the target group is exclusive, we sorted and extracted our data as per our requirements. For example, for the 2017 database, from its total 923,572 trip data, trips that only women make are filtered. Thus, 435981 trip data were used in this study. This cleaning process excluded data where our variables of interest have an invalid response like I don't know, not ascertained, etc. These values are usually coded as -1, -9, -10, etc. Therefore, we used the "select cases" option of Statistical Package for the Social Sciences (SPSS) to filter out invalid records. The datasets have their codes to denote different classes/categories. For our analysis, this study recorded the variables as per their need. A detailed description of this recording can be found in the following sub-section. This process involves "Recode into Different Variable" options of SPSS. The new variable is then used as input of the "Create Dummy Variables" tool to create dummies.

Variable used in this study. As mentioned earlier, this study recodes the variables of original NHTS data before using them. Table 1 shows how 11 of the 16 variables are recorded in this study. Of the rest of the variables, five are continuous variables. The dependent variable is the different travel modes of trips. There are 21-27 modes recorded in total in the three datasets. This study regrouped the modes into three groups where the 1st group consists of Non-Motorized Transport (walk, bicycle), 2nd group includes all kinds of public transportation, and the 3rd group has all other modes where Private Motorized Transports (PMT) (e.g., car, SUV, van) are dominant.

Table 2
Description of variables and category codes used in NHTS data and in this study

Variable name (Description)	Categories	
	Recoded in This study	Original categories in NHTS data
TRPTANS (travel mode)	NMT	walk, bike
	PT	school bus, public bus, paratransit, shuttle bus, intercity bus, rail, subway
	PMT and others	car, SUV, van, pickup, golf cart, motorcycle, RV, taxi, rental car, airplane, boat
AGE	abelow18	Below 18
	18to25	From 18 to 25
	26to35	From 26 to 35
	36to45	From 36 to 45
	45to55	From 46 to 55
	55to65	From 56 to 65
	above65	Above 65
FAMINC (Family income in USD	below25k	Below 25000 USD
	25to50k	From 25000 to 49999 USD
	50to75k	From 50000 to 74999 USD
	75to100k	From 75000 to 99999 USD
	above100k	Above 100000 USD
R_RACE (race of trip maker)	White	White
	Black	Black or African American
	Other	Asian, American Indian, Alaska Native, Hawaii Native, Multiple Race, Other race
EDUC (Maximum Education)	HSorBelow	Less than a High School, High School Graduate
	bachelors	Some College or Associate Degree, Bachelor's Degree
	graduate	Graduate Degree or Professional Degree
PRMACT (Primary activity performed last week)	work	Working
	withoutjob	Temporarily Absent from a job or business, Looking for work, Unemployed, Retired
	homemaker	Homemaker
	School going	Going to School
	other	Other
WHYTRP (purpose of the trip)	work	Going or Returning to work, Other work related
	home	To home
	school	School, Day care, Library, religious activity
	medical	Medical/dental service
	shopping	Shopping/errand, buy good, service, and gas,
	recreational	Social/recreational, visit relative, hang out, gym, family, funeral, pet, haircut
	transport	Pick up or drop off someone

Variable name (Description)	Categories	
	Recoded in This study	Original categories in NHTS data
	meals	Meals
	else	other
HOMEOWN (housing unit ownership status)	Home not owned	Rent, provided by military, other
	Home owned	Own
URBRUR	urban	Household in urban area
	Rural	Household in Rural area
Block group population density (person per square mile)	0_99	0 to 99 person/mile^2
	100_499	100 to 499 person/mile^2
	500_999	500 to 999 person/mile^2
	1000_1999	1000 to 1999 person/mile^2
	2000_3999	2000 to 3999 person/mile^2
	4000_9999	4000 to 9999 person/mile^2
	10000_24999	10000 to 24999 person/mile^2
	25000_99999	25000 to 99999 person/mile^2
Census tract Worker density (worker per square mile)	0_49	0 to 49 worker/mile^2
	50_99	50 to 99 worker/mile^2
	100_249	100 to 249 worker/mile^2
	250_499	250 to 499 worker/mile^2
	500_999	500 to 999 worker/mile^2
	1000_1999	1000 to 1999 worker/mile^2
	2000_3999	2000 to 3999 worker/mile^2
	4000_100000	4000 to 100000 worker/mile^2
DRVRCNT (driver in household)		Continuous variable
HHSIZE (member in household)		Continuous variable
HHVEHCNT (vehicle in household)		Continuous variable
TRPMILES (trip distance in miles		Continuous variable
NUMONTRP (number of trip companion)		Continuous variable

The independent variables used in this study can be viewed from three broad types. They are sociodemographic and household-related variables, trip-related variables, and built environment-related variables. Age, family income, race, occupation, and education are some commonly used sociodemographic attributes. Age was recorded and presented as

a continuous variable in the NHTS dataset. This study makes the first two categories "below 18" and "18 to 25". Then it makes four categories up to 65 with an interval of ten. The final class is "above 65". The recoding of the other four sociodemographic variables is shown in Table 1. The household characteristics include the ownership status of the housing unit, number of members, drivers, and vehicles in the household. The trip-related information includes trip length (in miles), number of companions in the trip, and trip purposes. Finally, the built environment-related variables are dummies for an urban area, the population density of the block group, and workers density (workers/square mile) of the census tract.

Data Analysis Method

For data analysis, this study first uses descriptive statistical techniques, including frequency distribution, percentage, mean, median, and standard deviation, to describe the variables. After that, inferential statistics are used to estimate the mode choice models. As the response variable is a categorical variable (i.e., NMT, PT, or PMT), Multinomial Logistic Regression (MLR) is used in this study. In regression, the conditional mean is expressed by E(Y|x) which means the expected value of Y given x. Here, Y is the response variable, and x is the predictor variable. The basic relation of conditional mean with predictor variable is $E(Y|x) = \beta 0 + \beta x$. In logistic regression we consider $0 \leq E(Y|x) \leq 1$ and is referred to as the probability of getting Y given x (here the probability of using non-motorized transport over the base category). The base category is PMT, and the model will separately generate probabilities of choosing NMT over PMT and choosing PT over PMT. The specific form of logistic regression used in this study is:

$$E(Y|x) = \pi(x) = \frac{e^{\beta_0 + \beta_x}}{1+e^{\beta_0 + \beta_x}}$$

And after the logit transformation this takes the following look: $\ln\left(\frac{\pi(x)}{1-\pi(x)}\right) = \beta_0 + \sum\beta_x + \varepsilon$

Here, $\pi(x)$ is the probability of choosing NMT or PT. β_0 is intercept, and β is the coefficient of the independent variable. ε is the residual or error term, and $1-\pi(x)$ is the probability of not getting Y (in this case PMT).

Chapter Four

Data Analysis Results

Descriptive Statistics

The frequency and percentages of the categorical variables are provided in Table 2. The mean, median, and standard deviations of numerical variables are also provided there. We have 490383, 509904, and 239153 valid observations for 2017, 2009, and 2001 data, respectively, where females took trips. The percentage of NMT and PT usage increased gradually over the year. The use of private motorized vehicles has always been the dominant mode (89%-92.9%). This study categorized age into seven cohorts, and among them, above65 has the highest percentage of women in 2009 and 2017 data. In 2001 data, 36 to 45 age group had the highest share. Racial dominance is attributed to the white population after they formed 82%-87% of the total respondents, despite the latest survey decrease. The percentage of the black community is almost doubled over the year 16-year period (from 2001 to 2017). The highest number of respondents have completed an associate degree or bachelor's degree. The percentage of this group and graduate degree holder have been increased over the time for the gradual decrease of the percentage of women with less than high school degree or just a high school degree. Income classes are kept the same to be consistent with three time periods, although there is an effect of natural inflation which led to the gradual decrease of categories under 75000 USD and increase of categories above it. Among the occupation, the ratio of women involved and not involved into work are almost unchanged in 2009 and 2017 data while these both categories had decreased from 2001. The percentage of homemakers is 11.5% in 2017, whereas in the other two surveys, it was 16%-17%.

Table 2

Descriptive summary of the categorical variables used in this study

	NHTS year	2017 Data		2009 Data		2001 Data	
	Categories	Count	%	Count	%	Count	%
Mode	NMT	40709	9.3	44690	8.8	15018	6.3
	PT	7237	1.7	5107	1.0	1872	0.8
	PMT	388035	89.0	460107	90.2	222263	92.9
Age	abelow18	11175	2.6	4500	0.9	11380	4.8
	18to25	22087	5.1	18648	3.7	16415	6.9
	26to35	57843	13.3	45564	8.9	38502	16.1
	36to45	60580	13.9	85771	16.8	59300	24.8
	45to55	75841	17.4	119007	23.3	51575	21.6
	55to65	100744	23.1	116127	22.8	30872	12.9
	above65	107711	24.7	120287	23.6	31109	13.0
Race	white	360375	82.7	443104	86.9	209408	87.6
	black	33489	7.7	30151	5.9	8622	3.6
	other	42117	9.7	36649	7.2	21123	8.8
Education	HSorBelow	91921	21.1	154089	30.2	102375	42.8
	bachelors	240735	55.2	272000	53.3	104867	43.8
	graduate	103168	23.7	83815	16.4	31911	13.3
Family Income	below25k	66843	15.3	81058	15.9	38725	16.2
	25to50k	89508	20.5	129070	25.3	77991	32.6
	50to75k	78601	18.0	96325	18.9	55134	23.1
	75to100k	62089	14.2	80111	15.7	34234	14.3
	above100k	138940	31.9	123340	24.2	33069	13.8
Activity	work	206133	47.3	232784	45.7	131700	55.1
	withoutjob	139683	32.0	154043	30.2	49002	20.5
	homemaker	50146	11.5	89711	17.6	38214	16.0
	School going	17129	3.9	10249	2.0	12389	5.2
	other	22890	5.3	23117	4.5	7848	3.3
Trip purpose	work	146167	33.5	169549	33.3	79491	33.2
	home	48804	11.2	47923	9.4	26975	11.3
	school	14136	3.2	14390	2.8	8050	3.4
	medical	9250	2.1	12192	2.4	4049	1.7
	shopping	96079	22.0	112675	22.1	51214	21.4
	recreational	46752	10.7	77506	15.2	33018	13.8
	transport	31493	7.2	36378	7.1	19369	8.1
	meals	34038	7.8	37295	7.3	15598	6.5
	else	9262	2.1	1996	0.4	1389	0.6
	Home not owned	95262	21.9	53029	10.4	38171	16.0
	Home owned	340719	78.1	456875	89.6	200982	84.0

	NHTS year	2017 Data		2009 Data		2001 Data	
	Categories	Count	%	Count	%	Count	%
	urban	343576	78.8	367236	72.0	177874	74.4
	Rural	92405	21.2	142668	28.0	61279	25.6
Block group population density	0_99	51321	11.8	61413	12.0	36157	15.1
	100_499	66784	15.3	88354	17.3	40958	17.1
	500_999	40028	9.2	48584	9.5	21873	9.1
	1000_1999	57187	13.1	72400	14.2	31273	13.1
	2000_3999	85013	19.5	101842	20.0	44938	18.8
	4000_9999	103764	23.8	108846	21.3	51584	21.6
	10000_24999	24347	5.6	22075	4.3	11280	4.7
	25000_99999	7537	1.7	6390	1.3	1090	0.5
Worker density	0_49	64097	14.7	109853	21.5	42118	17.6
	50_99	29729	6.8	38059	7.5	20047	8.4
	100_249	43508	10.0	65003	12.7	26702	11.2
	250_499	41839	9.6	67409	13.2	23106	9.7
	500_999	62110	14.2	80755	15.8	29958	12.5
	1000_1999	82805	19.0	73561	14.4	45179	18.9
	2000_3999	75496	17.3	46256	9.1	37872	15.8
	4000_100000	36397	8.3	28998	5.7	14171	5.9

Among trip purposes, work-related trips have been occupying one-third of the total trips. The following trip purpose with the second-highest percentage is shopping trips that occupy around 22% of the trips. Among the other trip purposes, recreational and home-bound trips are most common among women. Among the respondents, the renters are substantially lower than the owner of the housing unit. It's been only 10%-20% of respondents who rented a house. Similar to this percentage, respondents from urban areas form the highest share (72%-79%). This research also uses the collected data of the population density and worker density of the block group and census tract the respondent lives in. The major group of population density is 2000 to 10000 person/mile2 in all three surveys. Among the worker density groups, the categories with 0-49 worker/mile2 and 1000-1999 worker/mile2 have a high percentage of respondents.

Table 3 shows the descriptive statistics of the numerical variables used in this study. The mean number of drivers has decreased from 2.11 in 2001 to 1.89 in 2017. The

average number of members in a household has also decreased over the years. A gradual decrease has also been observed in the number of vehicles in households. The average trip distance for women was 9.14 miles in 2001, which slightly decreased in 2009 to 8.95 miles. However, in 2017, it increased to 10.75 miles. The average number of trip companions does not seem to have much variation over time and is in a range of 1.69-1.79 persons.

Table 3

Descriptive Statistics of numerical variables used in this study

Year	Statistics	DRVRCNT	HHSIZE	HHVEHCNT	TRPMILES	NUMONTRP
2017	Min	0	1	0	0	1
	Max	9	13	12	9621	301
	Mean	1.89	2.46	2.14	10.75	1.75
	SD.	0.814	1.289	1.191	72.4	1.674
2009	Min	0	1	0	0.11	1
	Max	9	14	23	9000	16
	Mean	2.02	2.68	2.27	8.95	1.69
	SD.	0.792	1.339	1.176	41.63	1.039
2001	Min	1	1	0	0.11	1
	Max	10	14	19	7000	100
	Mean	2.11	2.95	2.31	9.14	1.79
	SD.	0.798	1.4	1.164	40.63	1.365
Min is Minimum; Max is Maximum; SD. is Standard Deviation						

Factor of mode choice

This study builds three separate mode choice models for the three datasets using MLR. Each logit model uses the three categories of travel modes (i.e., NMT, PT, and PMT) as the dependent variable where PMT performs as the base category. The odds ratio of an independent variable tells us about the probability of choosing NMT or PT over PMT if

the independent variable is greater than one (for dummies) or increased (for numeric variable). The following subsections report the regression results of these three models.

Logit model using 2017 data. The regression result of the logit model using 2017 data is shown in Table 4. In the age variable, the last category (i.e., above65) serves as the base category where the probability of choosing NMT or PT by the other categories will be compared with the base category. Since the odds ratio of all the age cohorts except the base cohort is significantly less than one, it can be said that the probability of choosing NMT or PT by the other cohorts is less than that by the senior citizen cohort (above 65). Also, with a comparative assessment of the odds ratio of the other cohorts, it is clear that the probability of choosing an NMT increases with age. Similarly, except for the base category, the likelihood of choosing a PT over a car increases from the below 18 age group to the 36 to 45 age group and then decreases again.

Black women are more likely to choose NMT over PMT than white women. However, the case is reversed when it comes to choosing PT over PMT. White women chose PMT over the other two modes more than the women from other races (excluding black women).

The odds ratio for education variables is also significant. The women with high school or lower degree choose NMT 20.3% more than the women with a degree higher than high school. The women with a graduate or professional degree choose NMT less than the women with a bachelor's or associate degree. However, the odds of using PT over PMT are highest for the bachelor's group than the other two groups. The graduates have 30.3% less likelihood of choosing a PT, whereas it's 10% for the women with a high school or lower degree.

Except for the base class, all the income classes have significantly higher odds of choosing NMT over PMT. Also, these odds decrease with income; women are 50%, 43%, 33%, and 22.6% more likely to choose NMT than women of income class of above 100,000 USD when their annual salary is below 25000, 25000 to 49999, 50000 to 74999, and 75000 to 99999, respectively. For PT, it is only significant that the income class of 25000 to 49999 USD is 13.4% more likely to use PT over PMT.

The work-related activity is the base category of the activity variable. Compared to that category, women with all the other occupations have less probability of using NMT over the car. Among them, school-going females have the least probability (~50%). On the other hand, homemakers and women without jobs have a 25% and 93% more probability of choosing PT. School-going females and females involved in other activities have less odd of choosing this mode over PMT.

Trip-related attributes are highly important factors while choosing travel modes. If the trip length is longer, women have a 60% chance to choose PMT over NMT. However, for PT, it's almost the same as PMT. Similarly, if there are more trip companions, the odds of choosing NMT and PT reduces by 1.2% and increases by 4.8%, respectively. The odds of choosing NMT increases by 48%, 71%, and 516% when the trip is for home, school, and medical purposes. Odds of using NMT also increase for shopping, transport, and meals-related trips compared with work-related trips. However, for recreational and other trips, the odds of using PMT are higher than that for cycling, with respect to the reference group. On the other hand, for home and school-related trips, the odds of using PT is 60% and 40% less than PMT, compared to work-related trips. In trips for medical, shopping,

recreational, transportation and meal purpose, odds of using PT is higher than the odds of using PMT.

The household characteristics also affect the mode choice of women. Females in a rented housing unit are more likely to use NMT and PT over PMT than those in owned housing. The effect of having more drivers is not significant in choosing NMT. However, this factor reduces the odds of using PT significantly. In a similar pattern, having more vehicles in the household reduces the odds of using these two modes over PMT significantly. When the household size (the number of family members) increases, it reduces the odds of using NMT and significantly increases the odds of using PT.

The Built environment characteristics also important in explaining the mode choice. Women in urban areas are 23% more likely to choose NMT over PMT than rural women. Similarly, the odds of using PT over PMT is 11% higher for urban women than rural women. The effect of density on choosing NMT is not much significant. Only areas with extremely lower density (0 to 49 person/mile2) and extremely higher density (10000 to 100000 person/mile2) than the base density (4000-9999 person/mile2) have lower odds of using NMT. For choosing PT, all the other density categories have significantly lower odds of choosing it than the base category. For working density, the base category is 1000 to 1999 worker/mile2. Women from worker density lower than this mostly have higher odds of choosing NMT, and higher working density areas have lower odds of choosing NMT by women. Only working density 0 to 49, 500 to 999, and 4000 to 100000 are significant for choosing PT. The first category has a higher odd of choosing PT by women, whereas the last two categories have a lower odd of choosing PT than the base category's density. Women in urban areas are 23% more likely to choose NMT over PMT than rural

women. Similarly, the odds of using PT over PMT is 11% higher for urban women than rural women.

Table 4

Multinomial Logit Model for 2017 Data (base dependent variable: PMT)

		Category: Non-Motorized Transport			Category: Public transportation		
	Independent Variable Categories	Coeff.	Wald	Odds ratio	Coeff.	Wald	Odds ratio
	Intercept	-2.321	90.568		2.251	19.356	
Age	abelow18	-0.301	65.641	0.74***	-1.643	521.098	0.193***
	18to25	-0.523	210.263	0.593***	-0.873	134.214	0.418***
	26to35	-0.405	229.477	0.667***	-0.404	35.602	0.668***
	36to45	-0.214	60.019	0.807***	-0.097	1.846	0.908
	45to55	-0.295	143.475	0.745***	-0.210	9.668	0.811**
	55to65	-0.295	214.311	0.745***	-0.225	13.668	0.798***
	above65	Base					
Race	white	Base					
	black	0.332	136.504	1.394***	-0.522	203.660	0.593***
	other	-0.075	14.969	0.928***	-0.182	33.747	0.833***
Education	HSorBelow	0.185	108.844	1.203***	-0.100	11.148	0.905***
	bachelors						
	graduate	-0.306	410.825	0.736***	-0.402	115.871	0.669***
Family Income	below25k	0.404	304.733	1.498***	-0.040	0.955	0.960
	25to50k	0.356	339.513	1.428***	0.125	11.895	1.134***
	50to75k	0.284	233.848	1.329***	0.068	3.825	1.070
	75to100k	0.204	109.644	1.226***	0.042	1.347	1.043
	above100k	Base					
Activity	work	Base					
	withoutjob	-0.173	83.976	0.841***	0.229	18.187	1.257***
	homemaker	-0.106	22.655	0.899***	0.659	77.531	1.934***
	School going	-0.568	267.173	0.567***	-0.587	115.044	0.556***
	other	-0.201	52.684	0.818***	-0.768	243.294	0.464***
	Trip length	-0.930	22248.9	0.394***	0.000	4.177	1*
	Companion	-0.012	6.430	0.988*	0.047	235.300	1.048***
Trip purpo	work	Base					
	home	0.394	263.677	1.483***	-0.482	139.149	0.618***
	school	0.539	286.880	1.715***	-0.967	1016.083	0.38***

		Category: Non-Motorized Transport			Category: Public transportation		
	Independent Variable Categories	Coeff.	Wald	Odds ratio	Coeff.	Wald	Odds ratio
	medical	1.641	354.203	5.16***	0.103	1.235	1.109
	shopping	1.520	6010.665	4.574***	1.685	774.378	5.39***
	recreational	-0.556	1055.148	0.573***	0.498	123.995	1.645***
	transport	1.571	1909.390	4.813***	1.164	268.947	3.203***
	meals	0.814	1186.90	2.256***	1.153	268.708	3.166***
	else	-0.192	28.443	0.825***	-1.012	391.019	0.364***
	Home not owned	0.155	88.628	1.168***	0.127	18.430	1.135***
	driver in HH	0.009	0.468	1.009	-0.142	41.286	0.867***
	member in HH	-0.048	41.512	0.953***	0.127	152.367	1.135***
	vehicle in HH	-0.090	128.553	0.914***	-0.167	119.862	0.846***
	Urban	0.208	55.480	1.231***	0.111	5.099	1.118*
Block group population density	0_99	-0.148	9.905	0.863**	-0.452	25.111	0.637***
	100_499	-0.027	0.554	0.973	-0.250	12.200	0.779***
	500_999	0.014	0.168	1.014	-0.150	5.449	0.861*
	1000_1999	-0.010	0.135	0.990	-0.135	6.430	0.873*
	2000_3999	-0.002	0.013	0.998	-0.178	17.431	0.837***
	4000_9999	Base					
	10000_24999	-0.300	110.996	0.741***	-0.456	68.928	0.634***
	25000_99999	-1.061	544.487	0.346***	-1.841	707.447	0.159***
Worker density	0_49	0.170	18.397	1.185***	0.173	4.791	1.189*
	50_99	0.084	4.478	1.088*	-0.048	0.412	0.953
	100_249	-0.028	0.768	0.972	-0.062	0.952	0.940
	250_499	0.065	4.913	1.067*	-0.045	0.630	0.956
	500_999	-0.013	0.321	0.987	-0.152	11.750	0.859***
	1000_1999	Base					
	2000_3999	-0.169	61.939	0.845***	-0.064	1.992	0.938
	4000_100000	-0.416	185.200	0.659***	-0.752	151.810	0.472***
Model Diagnostic							
Log likelihood (intercept)		355483.84					
Log likelihood (full model)		246011.18					
N		435981					
Chi-Square		109472.60					
Pseudo R^2: Cox and Snell		0.211					
Pseudo R^2: Neglerkerke		0.393					
Pseudo R^2: McFadden		0.308					

Logit model using 2009 data. The regression result of the logit model using 2017 data is shown in Table 5. In the age variable, the last category (i.e., above65) serves as the base category where the probability of choosing NMT or PT by the other categories will be compared with the base category. Since the odds ratio for choosing NMT of all the age cohorts except the base cohort is significantly less than one, it can be said that the probability of choosing NMT by the other cohorts is less than that by the senior citizen cohort (above 65). Similarly, except for the base category, the likelihood of choosing a PT over the car for all the age groups is lower than the base group.

The odds ratio for education variables is also significant. The women with high school or lower degrees choose NMT 10.5% more than the women with associate or bachelor's degrees (base category). The women with a graduate or professional degree choose NMT less than the base category. However, the odds of using PT over PMT are highest for the bachelor's group than the other two groups. The graduates have around 15% less likelihood of choosing an NMT or PT than the ones with associate or bachelor's degrees.

All the income classes have significantly higher odds of choosing NMT over PMT than the base class (above 100,000 USD). Also, these odds increase with income. For PT, none of the effects are significant. The work-related activity is the base category of the activity variable. Compared to that category, women with all the other occupations have less probability of using NMT over the car. On the other hand, women without jobs and homemakers do not have different odds than working women to choose PT. School-going females and females involved in other activities have 55% and 39% less odd of choosing this mode over PMT.

Table 5

Multinomial Logit Model for 2009 Data (base dependent variable: PMT)

		Category: Non-Motorized Transport			Category: Public transportation		
	Independent Variable Categories	Coeff.	Wald	Odds ratio	Coeff.	Wald	Odds ratio
	Intercept	2.121	91.754		-37.030	2491.456	
Age	abelow18	-0.290	19.529	0.748***	-1.500	129.163	0.223***
	18to25	-0.292	71.155	0.747***	-0.369	10.552	0.691**
	26to35	-0.464	348.830	0.629***	-0.175	3.267	0.840
	36to45	-0.290	173.434	0.748***	-0.017	0.037	0.983
	45to55	-0.300	250.715	0.741***	-0.176	5.432	0.838*
	55to65	-0.224	175.841	0.799***	-0.219	10.438	0.803**
	above65						
Race	white						
	black	0.365	192.659	1.441***	-0.027	0.105	0.974
	other	-0.112	29.061	0.894***	-0.146	4.671	0.864*
Education	HSorBelow	0.100	55.858	1.105***	-0.158	10.601	0.854**
	bachelors						
	graduate	-0.215	238.464	0.806***	-0.166	8.089	0.847**
Family Income	below25k	0.159	59.320	1.173***	-0.142	3.545	0.867
	25to50k	0.171	108.141	1.187***	0.085	1.755	1.088
	50to75k	0.127	61.353	1.136***	0.082	1.620	1.085
	75to100k	0.073	19.343	1.076***	0.057	0.727	1.058
	above100k						
Activity	work						
	withoutjob	-0.208	189.980	0.812***	-0.101	2.695	0.904
	homemaker	-0.311	411.234	0.733***	-0.050	0.599	0.951
	School going	-0.089	4.534	0.915*	-0.814	65.457	0.443***
	other	-0.239	87.609	0.788***	-0.338	13.473	0.713***
	Trip length	-0.021	997.677	0.979***	-0.002	2.459	0.998
	Companion	-1.029	10536.636	0.357***	-0.156	47.570	0.856***
Trip purpose	work						
	home	0.933	1535.430	2.543***	-0.535	63.817	0.586***
	school	0.648	219.488	1.912***	-0.640	48.747	0.527***
	medical	1.256	465.768	3.512***	-0.025	0.032	0.975
	shopping	0.901	2673.666	2.463***	0.359	31.029	1.432***
	recreational	-1.206	9092.594	0.299***	-0.708	153.416	0.493***
	transport	0.844	817.977	2.325***	0.230	6.009	1.259*

		Category: Non-Motorized Transport			Category: Public transportation		
	Independent Variable Categories	Coeff.	Wald	Odds ratio	Coeff.	Wald	Odds ratio
	meals	0.168	48.144	1.182***	0.139	2.143	1.149
	else	-2.443	1690.903	0.087***	37.233		2.139***
	Home not owned	0.244	179.204	1.276***	0.071	1.185	1.073
	driver in HH	-0.120	111.482	0.887***	0.082	4.234	1.085*
	member in HH	0.164	695.492	1.178***	0.072	10.065	1.074**
	vehicle in HH	-0.121	321.821	0.886***	-0.170	41.135	0.844***
	Urban	0.052	7.347	1.053**	0.135	3.037	1.145
Block group population density	0_99	0.096	8.665	1.101**	0.315	5.463	1.371*
	100_499	0.119	21.453	1.126***	0.371	12.504	1.449***
	500_999	0.069	9.054	1.072**	0.411	18.284	1.508***
	1000_1999	0.080	18.119	1.084***	0.474	36.057	1.607***
	2000_3999	0.072	20.044	1.075***	0.282	20.115	1.326***
	4000_9999						
	10000_24999	-0.277	120.282	0.758***	-1.159	306.330	0.314***
	25000_99999	-1.962	2348.879	0.141***	-1.152	58.779	0.316***
Worker density	0_49	-0.008	0.084	0.992	0.265	5.498	1.303*
	50_99	0.034	1.467	1.035	0.170	2.136	1.185
	100_249	0.032	2.094	1.032	0.117	1.750	1.124
	250_499	0.050	5.850	1.051*	0.062	0.619	1.064
	500_999	0.080	17.611	1.083***	0.103	2.122	1.109
	1000_1999						
	2000_3999	-0.090	18.201	0.914***	-0.278	16.100	0.757***
	4000_100000	-0.341	202.728	0.711***	0.000	0.000	1.000
Model Diagnostic							
Log likelihood (intercept)		415757.11					
Log likelihood (full model)		124727.18					
N		509904					
Chi-Square		137286.60					
Pseudo R^2: Cox and Snell		0.143					
Pseudo R^2: Neglerkerke		0.257					
Pseudo R^2: McFadden		0.198					

Black women are more likely to choose NMT over PMT than white women. However, this is not significant when it comes to choosing PT over PMT. The females of

other races except these two also have lower odds of choosing NMT or PT than white females.

The work-related activity is the base category of the activity variable. Compared to that category, women with all the other occupations have less probability of using NMT over the car. On the other hand, women without jobs and homemakers do not have different odds than working women to choose PT. School-going females and females involved in other activities have 55% and 39% less odd of choosing this mode over PMT.

Trip-related attributes are a highly important factor while choosing travel modes. If the trip length is longer, there is a 2.1% less chance for women to choose NMT over PMT. However, the odd to choose PT is the same as PMT. Similarly, if there are more trip companions, the odds of choosing NMT and PT reduce by 65% and 14.4%, respectively. The odds of choosing NMT increases when the trip is for home, school, medical, shopping, meals, and transport purpose. However, for recreational and other trips, the odds of using PMT are higher than that for cycling and walking, with the respect of the reference group. On the other hand, for home, school, and recreational related trips, the odds of using PT is around 40%-60% less than that for PMT, compared to work-related trips. In trips for shopping and other groups, the odds of using PT are higher than the odds of using PMT. To perform trips with the purpose of meals and medicals, women do not differ between PT and PMT while choosing mode.

The household characteristics also affect the mode choice of women. Females in a rented housing unit are more likely to use NMT over PMT than those in owned housing. However, women from rented housing and owned housing don't significantly differ in choosing mode between PT and PMT. The effect of having more drivers reduces the odds

of using NMT significantly by 11.8%, while it increases the odds of using PT by 8.5%. In an intuitive pattern, having more vehicles in the household reduces the odds of using these two modes over PMT significantly. When the household size (the number of family members) increases, it increases the odds of using NMT and PT significantly.

The Built environment characteristics also important in explaining the mode choice. Women in urban areas are 5.3% and 14.5% more likely to choose NMT and PT over PMT than rural women. The effect of density on choosing NMT is also significant. Areas with lower density than the base category (4000 to 9999 person/mile2) have higher odds of using NMT (7.5% to 12%) and PT (32.6% to 60.7%) by women. Women in areas with density higher than the base category have lower odd of using NMT (24% and 86%) and PT (~69%). For working density, the base category is 1000 to 1999 worker/mile2. Women from worker density immediately lower than this mostly have higher odds of choosing NMT, and higher working density areas have lower odds of choosing NMT by women. For choosing PT, only working density 0 to 49 and 2000 to 3999 are significant. The first category has a 30% higher odd of choosing PT, whereas the second category has a 25% lower odd of choosing PT by women than the base category's density.

Logit model using 2001 Data. The regression result of the logit model using 2017 data is shown in Table 5. In the age variable, the last category (i.e., above65) serves as the base category where the probability of choosing NMT or PT by the other categories will be compared with the base category. Since the odds ratio of choosing NMT by all the age cohorts (except the base cohort) is significantly less than one, it can be said that the probability of choosing NMT by the other cohorts is less than that by the senior citizen cohort (above 65). Similarly, the likelihood of choosing a PT by females below 18 years

old is less than that by females above 65 years old. However, females with an age of 26 to 55 prefer PT 30%-83% more than the senior citizen base cohort. The odds of choosing it by other age cohort is the same as the base cohort.

Table 6

Multinomial Logit Model for 2001 Data (base dependent variable: PMT)

		Category: Non-Motorized Transport			Category: Public transportation		
	Independent Variable Categories	Coeff.	Wald	Odds ratio	Coeff.	Wald	Odds ratio
	Intercept	0.335	0.641		-2.701	6.739	
Age	abelow18	-0.230	11.101	0.795***	-0.689	22.711	0.502***
	18to25	-0.446	65.496	0.64***	0.243	2.843	1.275
	26to35	-0.392	74.308	0.676***	0.608	20.521	1.836***
	36to45	-0.252	33.855	0.778***	0.377	8.909	1.457**
	45to55	-0.381	86.846	0.683***	0.265	4.542	1.304*
	55to65	-0.333	71.553	0.716***	0.083	0.458	1.086
	above65						
Race	white						
	black	0.213	14.374	1.238***	-0.955	140.265	0.385***
	other	-0.045	1.661	0.956	-0.547	62.064	0.579***
Education	HSorBelow	0.191	69.532	1.21***	-0.171	7.504	0.843**
	bachelors						
	graduate	-0.238	68.815	0.789***	-0.259	10.400	0.772**
Family Income	below25k	0.197	23.142	1.217***	0.278	7.927	1.321**
	25to50k	0.228	45.417	1.256***	0.404	23.064	1.497***
	50to75k	0.144	17.981	1.155***	0.419	23.386	1.52***
	75to100k	0.051	1.948	1.052	0.037	0.181	1.038
	above100k						
Activity	work						
	withoutjob	-0.113	13.266	0.893***	0.281	8.375	1.325**
	homemaker	-0.157	30.278	0.855***	0.739	45.512	2.093***
	School going	-0.338	40.238	0.713***	-1.231	185.015	0.292***
	other	-0.142	7.345	0.868**	-0.054	0.155	0.947
	Trip length	-1.011	8779.053	0.364***	0.001	21.326	1.001***
	Companion	-0.054	29.850	0.948***	0.154	431.644	1.167***
Tr	work						

		Category: Non-Motorized Transport			Category: Public transportation		
	Independent Variable Categories	Coeff.	Wald	Odds ratio	Coeff.	Wald	Odds ratio
	home	0.221	33.475	1.247***	-0.897	163.276	0.408***
	school	0.360	36.193	1.433***	-1.006	169.864	0.366***
	medical	1.269	78.401	3.557***	-0.177	0.895	0.837
	shopping	1.061	1198.267	2.889***	0.961	96.983	2.614***
	recreational	-1.380	3127.264	0.251***	0.147	2.950	1.158
	transport	1.360	578.865	3.895***	1.291	68.014	3.636***
	meals	0.315	61.152	1.37***	0.949	37.403	2.583***
	else	-1.027	105.733	0.358***	-1.796	149.323	0.166***
	Home not owned	0.138	24.143	1.148***	0.092	1.832	1.096
	driver in HH	0.006	0.103	1.006	-0.123	8.077	0.884**
	member in HH	-0.041	14.296	0.96***	0.155	55.361	1.168***
	vehicle in HH	-0.084	47.214	0.919***	-0.318	87.606	0.728***
	Urban	0.139	15.646	1.15***	0.659	55.971	1.932***
Block group population density	0_99	-0.193	8.835	0.825**	0.514	8.074	1.672**
	100_499	-0.115	4.764	0.891*	0.179	1.447	1.196
	500_999	-0.027	0.299	0.973	0.208	2.110	1.231
	1000_1999	0.008	0.042	1.008	-0.189	2.962	0.828
	2000_3999	0.106	10.265	1.111**	0.045	0.253	1.046
	4000_9999						
	10000_24999	-0.232	23.788	0.793***	-0.739	59.322	0.478***
	25000_99999	-0.741	49.985	0.477***	-1.175	50.355	0.309***
Worker density	0_49	0.258	19.376	1.295***	0.182	1.243	1.199
	50_99	0.159	7.845	1.172**	0.246	2.360	1.279
	100_249	0.066	1.896	1.068	0.217	2.482	1.242
	250_499	0.173	14.578	1.189***	0.043	0.121	1.044
	500_999	0.069	3.373	1.071	0.106	1.057	1.112
	1000_1999						
	2000_3999	-0.034	0.959	0.967	-0.208	5.314	0.812*
	4000_100000	-0.464	87.383	0.629***	-0.774	47.960	0.461***
Model Diagnostic							
Log likelihood (intercept)		131963.74					
Log likelihood (full model)		89265.18					
N		239153					
Chi-Square		42698.60					
Pseudo R^2: Cox and Snell		0.164					
Pseudo R^2: Neglerkerke		0.381					

		Category: Non-Motorized Transport			Category: Public transportation		
	Independent Variable Categories	Coeff.	Wald	Odds ratio	Coeff.	Wald	Odds ratio
Pseudo R^2: McFadden			0.319				

Black women are 23.8% more likely to choose NMT over PMT than white women. However, they prefer PT 61.5% less than the white women. Women from the other races do not differ in choosing NMT from white women. But when it comes to choosing PT, the likelihood of their preference on it is 42% less than that of white women.

The odds ratio for education variables is also significant. The women with high school or lower degree choose NMT 21% more than the women with an associate or bachelor's degree (base group), while the women with a graduate or professional degree choose NMT 21% less than the base group. However, the odds of using PT over PMT are highest for the bachelor's group than the other two groups. The graduates have a 15.7% less likelihood of choosing a PT, whereas it's 22% for the women with a high school or lower degree.

The income classes up to 75000 USD salary have significantly higher odds of choosing NMT and PT over PMT than the base class (over 100000 USD) as well as the 75000 to 100000 USD class. The odds of the first three classes to choose NMT are 21.7%, 25.6%, and 15.5% more than the base class (above 100000 USD). On the other hand, for choosing PT, these odds are respectively 32.1%, 49.7%, and 52% more than the base class.

The work-related activity is the base category of the activity variable. Compared to that category, women with all the other occupations have less probability of using NMT over car than working women. On the other hand, women without jobs and homemakers

have 32.5% and 209% more probability than women with a job, respectively, to choose PT. School-going females and females involved in other activities have the same odd as working women.

Trip-related attributes are a highly important factor while choosing travel modes. If the trip length is longer, there is a 66% chance for women to choose PMT over NMT. However, the chance of choosing PT over PMT is slightly higher. Similarly, if there are more trip companions, the odds of choosing NMT and PT reduces by 5.2% and increases by 16.7%, respectively. The odds of choosing NMT increases by 1.2, 1.4, and 3.5 times of the work trips when the trip is for home, school, and medical purposes. Odds of using NMT also increase for shopping, transport, and meals-related trips when compared with work-related trips. However, for recreational and other trips, the odds of using PMT are higher than that for NMT, with respect to the reference group. On the other hand, for home and school-related trips, the odds of using PT is 60% and 65% less than PMT, compared to work-related trips. In trips for medical, transportation, and meal purpose, odds of using PT is 2.5-3.6 times higher than the odds of using PT in the work trip.

The household characteristics also affect the mode choice of women. Females in a rented housing unit are more likely to use NMT than those in owned housing, while for choosing PT, this factor does not play a distinguishable role. The effect of having more drivers is not significant in choosing NMT. However, this factor reduces the odds of using PT significantly. In a similar pattern, having more vehicles in the household reduces the odds of using these two modes over PMT significantly. When the household size (the number of family members) increases, it reduces the odds of using NMT and increases the odds of using PT significantly.

The Built environment characteristics also important in explaining the mode choice. Women in urban areas are 15% and 93.2% more likely to choose NMT and PT, respectively, over PMT than rural women. The effect of some of the density classes on choosing NMT is significant. The density class immediately lower to the base class has an 11% higher odd of choosing NMT. Women from areas with the two lowest density classes and two higher density classes have lower odds of choosing NMT than the base class. For choosing PT, only areas with extremely lower density (0 to 49 person/mile2) have higher odds of using NMT than the base density (4000-9999 person/mile2). The highest two density classes have a lower odd of choosing PT than the base class, while the effects of the other classes are insignificant. For working density, the base category is 1000 to 1999 worker/mile2. Women from worker density lower than this mostly have higher odds of choosing NMT, and higher working density areas have lower odds of choosing NMT by women. For choosing PT, only the highest two working density classes have significantly lower odds of choosing PT than the base category's density.

Fit of the models. At the bottom of each table discussed above, the model diagnostics are presented. Three types of Pseudo R2 have been presented. The fit of the models is moderately high and satisfactory. The McFadden's pseudo rho square is ranged between 0.20-0.32, which is reasonably high[1].

[1] "…its (McFadden's rho square) values tend to be considerably lower than those of the R^2 index...For example, values of 0.2 to 0.4 for ρ^2 represent excellent fit"-McFadden (1977)

Temporal change of effect of the factors

After discussing the role of the factors in individual datasets, it's another objective of this study to discuss the temporal variation of the effects of the factors. This section pulls out the role of each factor from the previous section and puts in a comparable graph to easily understand the temporal dynamics of the effects. The odds ratios are presented in the graph where the insignificant odds ratios are held to be one since the null hypothesis—the coefficient does not vary from the base category—was failed to be rejected.

Non-motorized transport choice. Figure 2 shows the odds of using NMT affected by different sociodemographic factors from the three datasets. Compared to work-involved women, the odds of using NMT by women from other occupations have always been lower. The bigger change is observed for school-going females and homemakers. In 2017 and 2001, their odds to use NMT were even lower than that in 2009. The odds for homemakers are higher in 2017 than in the other years. Compared to the richest group, the other income classes always have higher odds of using NMT over PMT. The odds in 2017 are the highest among the other two years for all of the income groups. This indicates that recently women from lower-income groups are inclined to NMT more than ever. The graduates always have lower odd, and high school graduates have higher odds of using NMT than the bachelor's group. These did not change much over the year. The usage of NMT among black women compared to their white counterparts increased dramatically in 2009 from 2001 and then slightly decreased in 2017. All the age groups have lower odds than the highest age group, and no substantial change or discernible pattern has been observed.

Figure 3 shows the odds of using NMT affected by different household and trip-related factors from the three datasets. Having more vehicles and more drivers is found to

reduce the odds of using NMT, and there is not much difference in effect over the years. Having a household larger in size works towards choosing NMT only in 2009. There have been some large changes in the odds ratio for the different trip purposes. The odds of meals, transport, shopping, and other trip purposes in 2017 are the highest among three years, and they were lowest in 2009. In trips for recreational and medical purposes, odds are also highest in 2017 and almost identical in the other two years. The odds for school and home-related trips were lowest in 2001, then hit the maximum point in 2009, and then get reduced in 2017 again. Having more trip companions and performing longer trips reduced the odds of using NMT. This reduction is highest and lowest in 2009, respectively.

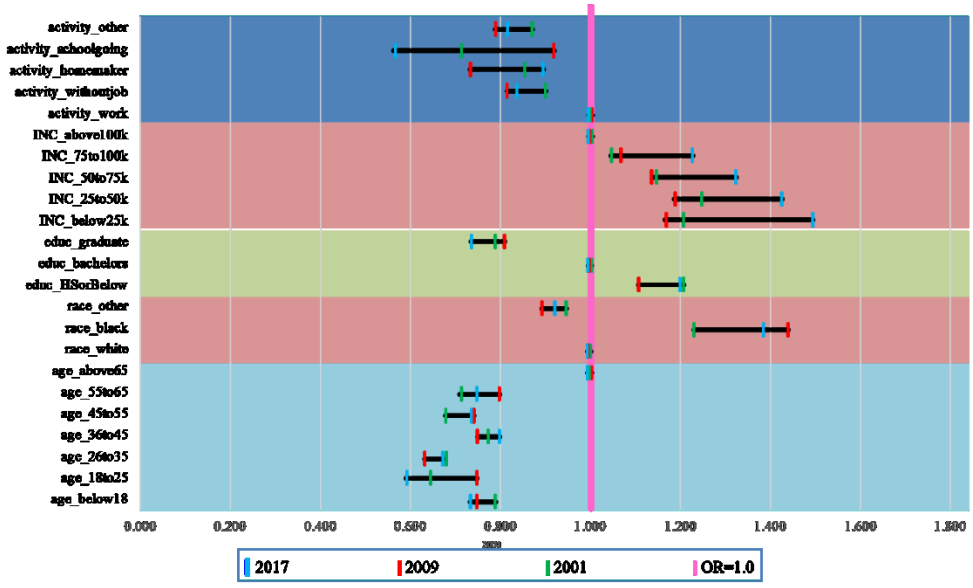

Figure 2. Odds Ratio (OR) of sociodemographic factors for NMT choice of all years

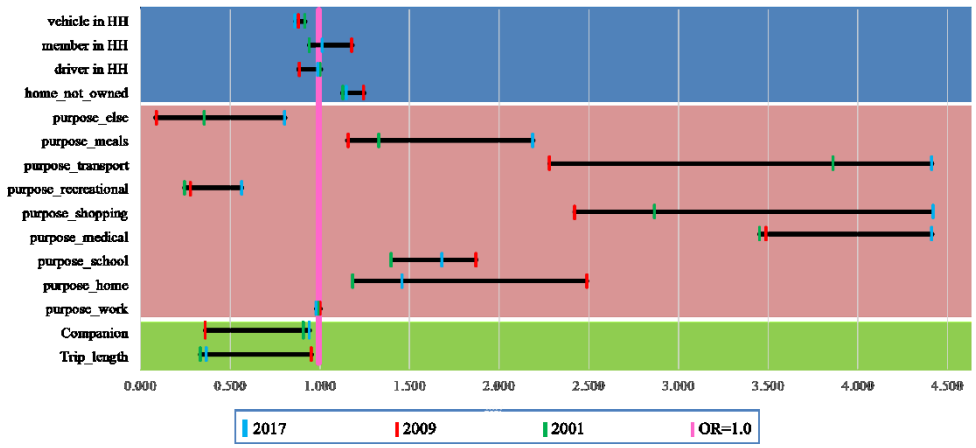

Figure 3. Odds Ratio (OR) of household and trip-related factors for NMT choice of all years

For population density, the two categories with the lowest density have lower odds of using NMT (Figure 4). The other low-density classes mostly have higher odds, and these odds were highest in 2001. For working density, the highest two categories have the lowest odds in 2017 and 2009. Similarly, the lowest categories have the lowest odds in 2001 and then in 2017. Areas with other working densities mostly had higher odds to choose NMT by women in 2009. In the other year, the effect was the same as the base category. Odds for urban women decreased in 2009 from 2001 and then again increased and surpassed all in 2017.

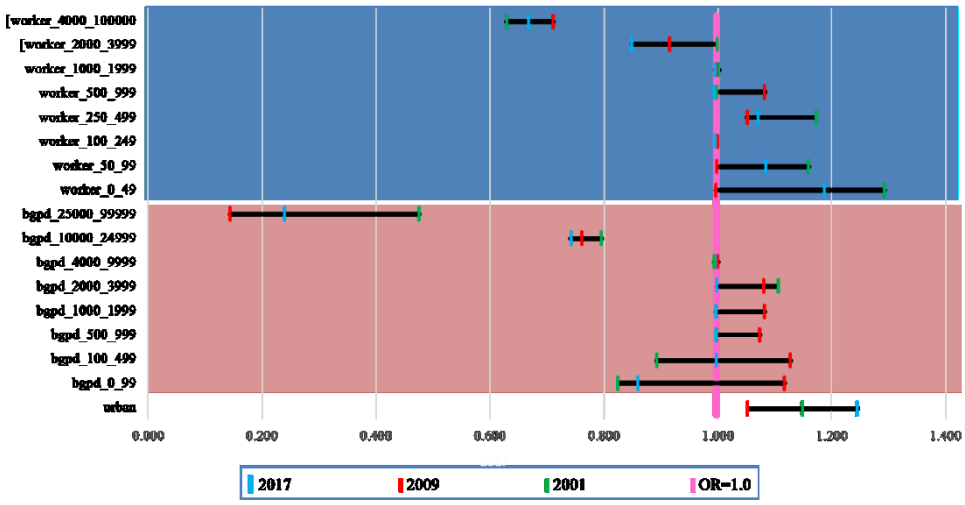

Figure 4. Odds Ratio (OR) of built environment-related factors for NMT choice of all years

Public transport choice. Figure 5 shows the odds of using PT affected by different sociodemographic factors from the three datasets. Compared to work-involved women, the odds of using PT by homemakers and women without a job are highest in 2001 and then in 2017. In 2009, these two groups preferred PT as like as working women. The odds for school-going females are lowest in 2001, then increased in 2009 and 2017. Females with other occupations have lower odd in 2017 compared to odds in 2009. Compared to the richest group, the other income classes always have higher odds of using PT over PMT. But these effects are most significant in 2001 and 2017. For the lowest income class (below 25000 USD), odds were lower in 2009 and higher in 2001 than the base group. This indicates that women from lower-income groups were inclined to PT in 2001 more than the recent times. The highly educated (graduates) and low educated (high school) have lower odds of using PT than the base group (bachelor's). These did not change much over the year. The usage of PT by black women compared to their white counterparts is lower

in 2001 than in 2017. All the age groups had lower odds in 2009 and 2017, while many had higher odds in 2001.

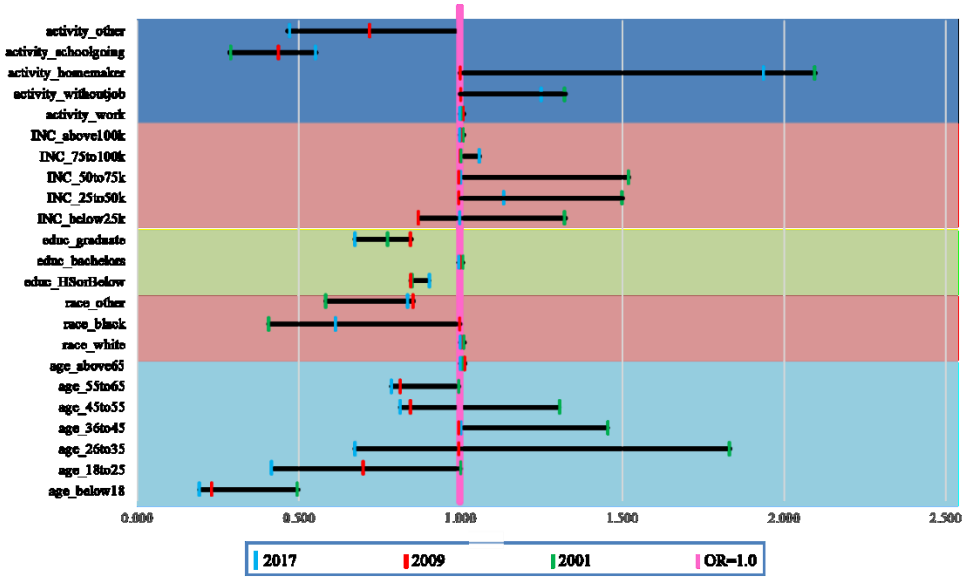

Figure 5. Odds Ratio (OR) of sociodemographic factors for PT choice of all years

Figure 6 shows the odds of using PT affected by different household and trip-related factors from the three datasets. Having more vehicles and more drivers are found to be mostly working to reduce the odds of using NMT, and there is not much difference in effect over the years. Having more family members works towards choosing PT. Home-renters have higher odds only in 2017. There have been some large changes in the odds ratio for some trip purposes. The odds of meals, transport, and shopping purposes are mostly higher than work purposes, and these higher odds were first reduced in 2009 and then again increased in 2017. Recreational trips had a lower odd of using PT in 2009 and higher odd in 2017. The odds for school and home-related trips were lower than work purposes and did not have much temporal variation. Having more trip companions slightly increased odds in 2001 and 2017 but decreased in 2009. Trip length does not have an effect on choosing PT over PMT.

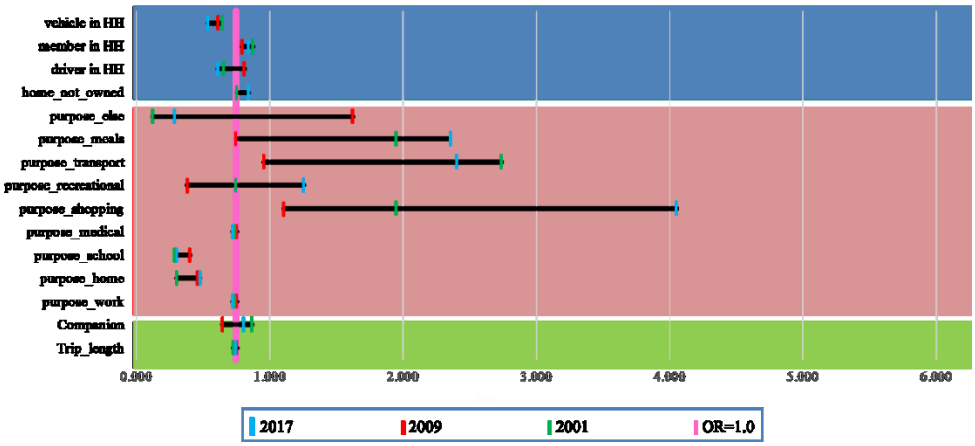

Figure 6. Odds Ratio (OR) of household and trip-related factors for PT choice of all years

For population density, the categories with lower density than the base group did not have a different effect in 2001. However, the odds increased there in 2009 and decreased in 2017. The other two highest density classes have lower odds. For working density, the effect of most the classes in most of the year does not statistically significantly different effect than the base group. The two highest categories have the lowest odds. Similarly, the lowest categories had the highest odds in 2009 and then decreased slightly in 2017. Odds for urban women were highest in 2001 and reduced in 2017. In 2009, no difference between rural and urban areas was observed in choosing PT.

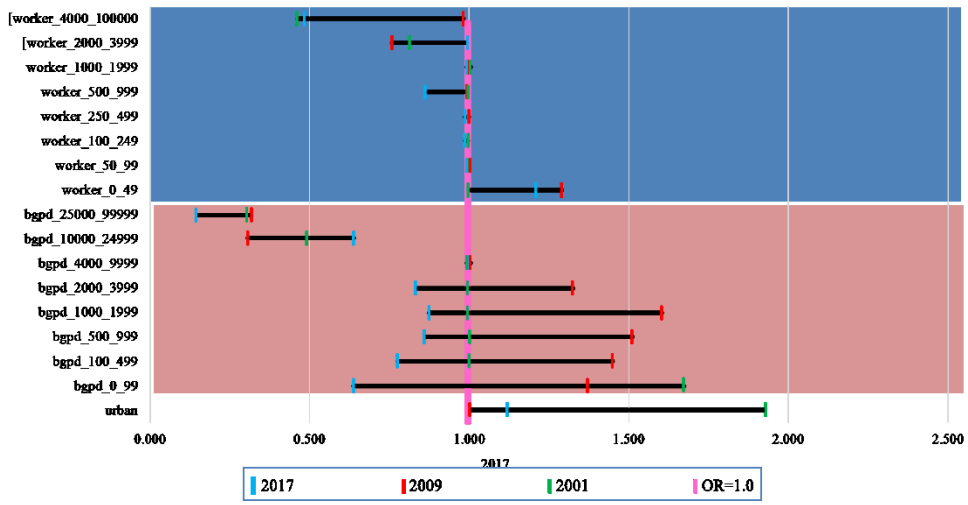

Figure 7 *Odds Ratio (OR) of built environment-related factors for PT choice of all years*

Chapter Five

Conclusions, Recommendations, and Policy Implication

Conclusion of the study

Choosing a mode for traveling depends on many personal, economic, attitudinal, social, and many other factors. This research explores the roles of different sociodemographic, household-related, trip-specific, and built environment-related factors in choosing travel mode by women in the USA. Although the dominant mode in the USA is a private motorized vehicle, this research is particularly interested in revealing the factors affecting choosing NMT or PT by women. This research, using three NHTS datasets from 2001, 2009, and 2005, builds three logit models to understand the mode choice of women. The independent variables used in this study can be viewed from three broad types. They are sociodemographic and household-related variables, trip-related variables, and built environment-related variables. Age, family income, race, occupation, and education are some commonly used sociodemographic attributes. The household characteristics include the ownership status of the housing unit, number of members, drivers, and vehicles in the household. The trip-related information includes trip length (in miles), number of companions in the trip, and trip purposes. Finally, the built environment-related variables are dummies for an urban area, the population density of the block group, and workers density (workers/square mile) of the census tract.

As there are several categories of each variable and they participated in three models, it is often hard to find a single generalized outcome. Despite it, this paragraph outlines and discusses the generalized findings on each variable. With the increase of age, the inclination towards cycling/walking increases, and women above 65 have the highest

inclination. The inclination for choosing PT also increases until they reach mid-age (36 to 45), and after that, women get inclined towards PMT. Proper safety around bus stops, the complexity of boarding/alighting, physical disability, etc., might play a role in deterring older women from using PT. Black women prefer NMT more than white women but do not prefer PT more than them. The white women prefer NMT and PT more than other races (except for black women). This finding is interesting and can be further investigated by future research to see if there any effect of income classes on the white women to choose PT more than the black women. Preference to choose NMT diminishes with educational qualification. However, it's encouraging that bachelor's or associate degree holders prefer PT more than the others. Preference to choose NMT also diminishes with the betterment of economic condition. This is quite intuitive since solvent women can afford private vehicles more than low-income people. Preference towards PT does not seem to differ much among the income classes in the last two surveys. However, in 2001, women with better economic tended to choose PT more, which peaked for 50000 to 75000 USD classes. After that, the odds of choosing PMT increased. Working women use NMT more than women with other occupations. School-going females prefer it least. However, the inclination towards PT is not the same as NMT. Homemakers and women without jobs use it more than the working women, while the others prefer it less.

The household-related characteristics also provided some insights about mode choice, although small in effect. Household size ambiguously affects choosing NMT in different years while consistently affecting choosing PT by increasing the likelihood. Dependency on PT and NMT also increases when the number of vehicles and drivers is

low or zero. Renters tend to opt for NMT over PMT, whereas choosing PT does not differ much from owners.

To make recreational trips, women prefer NMT less than they would do for a work trip. However, for the other kind of trip (e.g., for shopping, school, home), their preference for NMT is higher than that for a work trip. This essentially means that women during work trips depend on NMT less than they do during most of the other trips. However, they choose PT for a work trip more than they would do for school and home-related trips. With more companions and for longer traveling, women do not prefer NMT, whereas it is almost the same for them when they have PT and PMT as their modal options.

Women in urban areas are more inclined to NMT and PT than rural women. This research finds peak population densities below and above which the likelihood of choosing NMT and PT is low for women. For NMT, women in areas with 500 to 9999 person/mile2 density choose NMT more than the women living in gradually denser or less dense areas. For PT, the peak density is 4000-9999 person/mile2. The effect of worker density is not much stronger in mode choice. Still, we found a diminishing relationship between worker density and the likelihood of using PT and NMT.

Policy Implication

This research finds some important characteristics that would help policymakers formulate policies targeting specific social groups and geographical locations. It urges planners and policymakers to emphasize public transit infrastructure (e.g., transit shelter, route information, disability-friendly infrastructures) to help older women use more public transit. The areas dominant by the black community should be targeted to provide infrastructures like bike lanes, sidewalks, pedestrian crossings, etc. Since the likelihood of

more educated women to use NMT is less than the less educated women, social campaigning may help to encourage educated women to use NMT more. With that, researchers can investigate the reasons behind their low usage, which may have a reason like safety. Bikeshare program and transit facility and accessibility should aim at the economically depressed zones since their likelihood to use NMT and PT is high. Companies should allow poor people without credit cards to access bike-share, scooter-share with cash. Also, transit facilities can be made cheaper to help this community. Finally, since both the activity and trip purpose variables indicate a higher probability of using NMT by working women, the campaigning program should aim at commuting women. Finally, areas with high worker density, where the odds of using NMT and PT are low, should be targeted for future research and for finding scope to promote these two sustainable modes. Similarly, areas with extremely high and extremely low population density should also be prioritized.

A sustainable transportation system is a much-sought solution in today's world to solve the modern urban transportation problem, establish social equity, mitigate congestion and check environmental pollution. Public transportation, active transportation, and shared and connected mobility are showing the light in the debate. The findings implied with this research will help policymakers promote sustainable transports in the USA with an emphasis on social equity for women.

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