EVALUATING PREFERENCE FOR PERSONAL VEHICLES USING A LATENT FACTOR MODEL

A Thesis

by

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ABSTRACT

Automobiles have brought rapid changes in transportation with people from different areas and backgrounds jointly contributing to its diversity and complexity. This has given rise to unique needs and behaviors when it comes to making travel decisions. As such, there is a need to study these characteristics and plan for a more efficient and robust transportation system in the future. In this research, Factor analysis and Structural Equations Modeling (SEM) were used to derive hypothesized causal relationship of car mode choice with identified and selected variables of livability, alternative modes of transportation and socio-demographic data from a National level postal survey for sampled adults. It consisted of a literature review on factors associated with travel behavior in past studies and incorporated an exploratory and confirmatory analysis for a more comprehensive SEM model.

The results from the analysis indicated that an increase in the importance of alternative modes of transportation or an improvement in the quality of Recreation and Services would reduce the preference for cars in daily trips when there are no moderating effects. A multi-group analysis revealed that an increase in the quality of Recreation and Services would lead to a decreased preference for automobiles in transit available areas whereas it would increase for transit non-available areas. Also, older people would prefer more automobiles in the presence of transit and lesser in the absence of it. While working status had no effect on the nature of the relationships, it did influence working and non-working people differently. This study offers analytical evidence for debating the role of community livability on influencing driving as the travel mode. It also provided a structure of inter-relationships among the variables and the latent underlying constructs which presents a framework for any future improvement strategy.

DEDICATION

To my family

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This study uses data from the National Community Livability Survey 2017 sponsored by USDOT and National Center for Transit Research, University of South Florida conducted by Texas A&M Transportation Institute under the leadership of Jonathan Brooks. All other work for the thesis was completed independently by the student.

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CHAPTER I

INTRODUCTION

Transportation and its role

Transportation has been around for centuries, evolving in its form in terms of both technology and importance in today's modern society. It has played a leading role in the economic, sociological and environmental development of the society. The evolution of transportation modes, facilitated by technology and planning, from foot and animal carriages to motor vehicles and mass transit vehicles have contributed vastly to the expansion of urban settlements. The results of these advancements have been highly profitable, especially to the working population, whose daily commutes have become less problematic and more convenient. Apart from providing mobility to people and goods, it also influences the growth and economic activity patterns through land accessibility (*1*). In view of this importance, transportation is pivotal to the society and requires an efficient planning system for smooth operations and management of its infrastructure.

Transportation planning and Travel demand

Transportation planning acts as a mediator for connecting societal goals and objectives to transportation projects. The Institute of Transportation Engineers (ITE) defines transportation planning as a collaborative and participatory process involving people and organizations at various levels which examines demographic and travel characteristics of an area to evaluate future system improvements (*2*). The focus of this planning process is to analyze the current condition of the system and suggest new alternatives based on the evaluation of relevant performance measures.

History suggests that widening of roads and building new infrastructure has not always proved to be a complete solution. Also, the growing concerns of environmental impacts of building new transportation infrastructure and the limited availability of investments to fund such projects have often demonstrated the need for a better utilization of the available resources. This need gave rise to the concept of Travel Demand Management (TDM) which is an effective way of finding transportation alternatives to better manage the demand for travel. According to Federal Highway Administration (FHWA), TDM can be construed as a simple demand management which involves providing effective choices to travelers for improved travel reliability (*3*). Steg and Valek's study (as cited in Garling et al. 2002) classified TDM into two categories- measures which discourage car use (push measures) and measures which encourage the use of alternative transportation modes (pull measures) (*4*). Both descriptions are effectively aimed at identifying strategies for decreasing the dependence on automobiles for travel. This study uses an analytical approach to study similar dependence on automobiles.

Livability and its significance

Livability, as a term, does not have a defined meaning but is often understood in terms of its usage in a context. Among others, it is used in the context of community development, resilience, quality of life research and transportation (*5*). United States Department of Transportation (USDOT) defines livability in transportation as,

"Livability in transportation is about using the quality, location, and type of transportation facilities and services available to help achieve broader community goals such as access to good jobs, affordable housing, quality schools, and safe streets." (*6*)

It impacts the efficiency of existing investments and policies while improving public reach between activity centers. Livability in this paper has been used in reference to livability in transportation. This idea of livability when applied in a planning sub-domain, deals with developing a community which is capable of having all the aforementioned amenities and improves the quality of life of its residents. Livability, as a concept in transportation, is based upon a foundation of six principles (*6*)-

1. **Provide more transportation choices**- Developing a sage and economic transportation environment for alternative modes of transportation which would decrease vehicle miles of travel. A coordinated transportation plan with regional support would improve air quality and promote public health.
2. **Promote equitable, affordable housing-** Providing energy efficient housing for people in all age and income groups. Ensuring access to quality housing with reduced combined costs of housing and transportation.
3. **Enhance economic competitiveness-** Improving transportation access to business centers whilst promoting workforce education and diversifying economic opportunities.
4. **Support existing communities-** Focusing strategies for investment towards revitalizing the existing communities. Involves retrofitting communities with complete streets, mixed land uses and public spaces for a better utilization of current resources.
5. **Coordinate and leverage Federal policies and investment-** Encouraging strategies for sustainable development and promoting regional collaboration for energy efficient approaches. Leveraging federal policies and investment to enjoy benefits of coordinated investment process.

6. **Value communities and neighborhoods-** Enhancing the characteristics of communities which include safe and healthy status of residents while promoting walkable and crime free streets.

While people can have different ideas of livability, the above-mentioned principles are broader in terms of their application and objectives. Livability is often directly related to a better quality of life and good community. As such, the survey data used in this study had questions which were related to factors derived from the six livability principles.

Need for Research

The ever-increasing number of automobiles is a topic of concern for the future of transportation. In 2016, the percentage of workers who drove alone to work was greater than 70% in 47 states of the United States, averaging 76.4% overall (*7*). Also, the vehicles per 1000 people in the country have risen to 800 people, growing at a rate faster than licensed drivers since 1985 (*8*). This raises a few questions like-

- How does surrounding factors contribute to personal vehicle use?
- What are the ways to reduce automobile usage in favorable environments?
- What importance does people place on other modes of travel?
- What role does demographic play in such scenario?

Objectives

This study is an attempt to answer the questions of concern by aiming at the following objectives-

- To identify factors contributing to livability and how they associate among themselves.
- To understand causal relations with the preference for personal vehicles.

- Incorporating demographic variables to study their effects.
- Study of possible moderating effects by using binary variables.

Thesis Organization

This thesis is divided into a total of six chapters following this chapter. Chapter II talks about the past literature in the field of travel behavior with surrounding factors and provides a summary of the gaps in those researches. Methodology used in this study has been described in Chapter III including the factor analysis and Structural Equation Modelling (SEM) and how they were assessed using fit indices. Chapter IV deals with the survey data used in this research and a preliminary analysis of the relevant questions in the survey. The analysis has been described in Chapter V which comprises of the models formulated in this thesis and how they were used later. Chapter VI presents the results obtained from the models and talks about interpreting results. The last chapter provides an overview of the study and discusses the role of the key variables identified in this research and their impact on the preference for car as a travel mode. References and Appendix contains the sources cited in this text and the survey instrument of the data used in this thesis respectively.

CHAPTER II

LITERATURE REVIEW

This chapter provides relevant background information about travel behavior and mode choice decisions based on existing research in the field. It also reviews the modeling techniques used in the past to model travel behavior among different geographic and methodological settings.

Travel Behavior and Survey data

As the need for a proper explanation of transportation use grew, researchers started finding ways to model or analyze different measures/metrics related to travel demand to find a conclusive and reliable answer. These measures included key aspects of travel such as Vehicle Miles of Travel (VMT), Travel time, Origin and destination, Trip duration, mode choice, among others. Different factors have been studied in past research in an attempt to explain the uncertainty and changes in travel behavior over time. National Household Travel Survey (NHTS), census and other relevant survey data has been analyzed in many studies for the same reason.

Charles (1994) studied the regional travel characteristics in relation to changes in certain aspects of travel behavior by comparing the results of the 1990 household survey in the San Francisco Bay Area with the surveys conducted in 1965 and 1981 along with decennial census data (*9*). They used travel time expenditures, average trip duration and regional household trip rates to study travel behavior changes during the study period. Their results indicated that in-vehicle trips per household increased from 1965 to 1981 and then decreased in 1990 while vehicle trips were

increased by 74% overall. This indicates some influences of household and vehicle availability which affected the vehicle mode selection.

Scuderi and Clifton used Bayesian Belief Network on the 2001 NHTS survey add-on data for Baltimore region. Mode choice was analyzed with respect to land use and socio-demographics data for households using individual and household trip records (*10*). Their findings indicated that large concentration of residential and mix land uses accounted for a high probability of transit and other non-motorized trips. It also showed a weaker influence of land use variables on mode choice on a coarser level of spatial aggregation (census tract to zip level). This indicated a need to further evaluate the potential relationship between demographics specially vehicle count and land use on a larger spatial level.

Factors affecting travel behavior

Socio-demographics

Polk (2004) presented an attitudinal travel research to study gender influences on car use in Sweden in 1996. Among the socio-demographic variables studied, gender roles were significant in the respondent's willingness to reduce car use (*11*). The results implied an inclination of the conventional models to explain men's behavior when accounted for demographics. The inclusion of contextual factors like environmental and habitual behaviors showed striking differences between men and women. The research also highlights a possible use of latent variable model for a more explanatory analysis of the presented relationship. Whereas, Zhu et al. (2017) uses long term GPS collected data instead of a travel survey for predicting social demographic information (*12*). They filtered Home based trips and chose travel behavior variability to find correlation between individual demographics and factors like departure time, travel time, driving time and

location entropy. Their results showed a strong relationship for an individual's employment status and travel behavior variability.

Activity participation

While socio-economic characteristics have been included in most researches, they are usually bundled with other characteristics. Lu and Pas (1999) incorporated activity participation along with socio-demographics to study their interrelationships with travel behavior by averaging data collected on two consecutive days (*13*). They used number of trips, number of chains, travel time and car mode share as the predictors for travel behavior while activity participation was divided into in-home and out-of-home activity types for a survey sample of 2514 individuals. Their model explained the significant effect of activity participation on travel behavior and provided a more comprehensive analysis for estimating future travel behavior relationships. Although, inclusion of more relevant factors and a more representative sample is recommended for reproducing the analysis on a larger scale.

Similar study by Bifolio et al. (2010) presents more evidence of considering activity patterns while modelling travel behavior. They studied activity patterns in a trip chain model for modelling both daily and weekly data (*14*). The consistency of the estimates showed an accurate computation of time and mode attributes of travel demand. Hoorn (1979) used 5 groups of people- Working men and women, Housewives, students and other people for analyzing primarily the trip rates and travel times across the respective groups (*15*). This separation helped in accounting for the different activity patterns and travel behavior across the groups. Trip rate was not affected by factors like car ownership, car availability and degree of urbanization in any group while travel time was higher for people in larger cities. This analysis using regression was however concluded as more

descriptive and a better method was deemed necessary for supplementing the theoretical model introduced in the study.

Attitude in mode choice

Kuppam et al. worked on a set of three multinomial models which included individual and combined models of socio-demo and attitudinal variables to test their relationship with mode choice behavior. They employed a factor analysis approach to summarize the multitude of attitudinal and preference related variables (*16*). The results showed that the inclusion of both variables to be statistically more significant than the individual models, particularly attitudinal variables, which had twice the amount of impact.

Van et al. (2014) used data from six Asian countries for analyzing the intention to use one of three modes for work travel- car, public transit, or other modes. Dependent variables consisted of different attitudinal constructs- symbolic/affective, instrumental and social orderliness and a mix of logit models were analyzed (*17*). Attitudinal factors for car were found significant determinants for the entire sample. Desire to use car was identified as a pivotal factor which influenced the behavioral intention to commute in the sample.

Similar study by Lois and Lopez-Saez (2009) used an SEM approach to validate the hypothesis of the effects of affective and symbolic aspects of attitude in conjunction with the practical/instrumental motivations on the frequency of car use classified in categories based on the reasons for travel (*18*). Affective aspects were key predictors of the frequency of car use when accounted for both instrumental and symbolic aspects. Though their model did not account for other variables and hence lacked estimate reliability for a comprehensive estimate of causal dependence.

Built environment/Urban form

Contrary to the conventional approaches of using only socio-demographics or a combination of activity patterns, researchers in the 21st century considered the possibility of including different factors of land use and urban form in an attempt to further advance the area of travel behavior research. Among such studies, Boarnet and Crane (2001) emphasized the complex relationship of urban form and travel behavior by using three separate multivariate regression models. The factors included land use variables, socio-demographic control variables and trip time-cost variables. Their findings indicate the influence of the land use variables on travel behavior through the changes in price of travel (*19*). The importance of the scale of the study along with the possibility of residential self-selection has also been mentioned explicitly.

Another study by Aditjandra et al. (2012) used an SEM model to evaluate the role of neighborhood design on the travel behavior for the residents of certain parts of United Kingdom (UK) who reported residential relocation (*20*). Unlike previous studies which had a possibility of individual self-selecting a neighborhood with specific characteristics (residential self-selection), this study incorporated an SEM approach for relocated residents to negate that scenario. This study confirmed the previous researches on the effect of built environment and attitudes on travel behavior while accounting for socio-demographics by considering the changes in car ownership and driving behavior as the endogenous variables in the model.

Schwanen and Mokhtarian (2005) specifically talks about mode choice in a neighborhood type context for the residents of San Francisco Bay area. Their hypothesis is based on measuring neighborhood type dissonance which is identified as a mismatch between a commuter's current neighborhood and their preferences regarding the physical characteristics of a neighborhood (*21*). The consideration of resident's preferences helped in keeping the residential self-selection in check

and resulted in an autonomous effect of neighborhood type in the final model, although residential self-selection was apparently present. It suggested the use of more indicators related to social and dwelling components of the neighborhood into the model for dissonance.

Bagley and Mokhtarian (2002) conducted a similar research evaluating neighborhood type impact on travel behavior using SEM approach. However, their study suggested very little to no effects of residential location on travel behavior which indicated no direct causality between the two variables (*22*). A possible explanation was the lack of past research and proven theoretical relationships which are consistent across all studies. This also shows the wide openness of this domain for interpretation and a need for continued research for more robust conclusions.

Livability approach

Livability and transportation have been closely linked with each other due to the nature of their interaction and conflicts in all environments. Some studies have associated accessibility and urban form as a measure of livability and how those impact travel behavior (*23*, *24*). Cervero and Duncan (2006) concluded that having jobs within four miles of home could reduce motorized work travel by using regression on dependent variables of vehicle miles traveled (VMT) and vehicle hours traveled (*24*). Wesley (2013) used a case study from Denver region to assess a framework of 12 transportation related elements by using clusters of different domains of livability, linking livability scores to transportation objectives. However, their research was limited to Transit Oriented developments geography and lacked data support (*25*). Other studies also presented their ideas but were mostly related to built environment, urban form and other factors already discussed earlier.

Summary

The literature review suggested different measures and methods used in the past to study the essence of travel behavior. Though, it also suggested the gaps and limitations of these researches in terms of the scope and nature of their work.

- The factors studied in the past research have been related to measures of built environment, land use and attitudinal behaviors. However, this research includes user perceived set of indicators which are asked specifically in the context of their contribution to the community livability.
- Studies in the past have used different indicators of travel behavior like trip rates, Vehicle Miles Traveled (VMT), trip length, duration etc. to build various regression and statistical models. This study, by considering latent variable measuring current and speculated future automobile use from the user's perspective, aims to analyze the causes and favorable environments in which a user prefers to choose a personal vehicle.
- Although Structural Equation Modelling (SEM) has been used before in different studies, its use in this research provides a greater advantage due to its statistical prowess.
- Lastly, a lot of studies have focused on particular cities or regions in their analysis and hence, lack nation-wide application. This research, by using a National data sample, addresses that gap.

CHAPTER III

METHODOLOGY

The livability variables selected from the preliminary analysis of the data were further subjected to a two-step approach-

- Examination to validate the approach of a factor analysis, which was accomplished with the use of an exploratory factor analysis.
- Building a structural equation model for the ultimate assessment of factor relationships and potential effects.

Variable Types Used

The variables used in this study are classified according to their role in the research as- measured and latent variables.

1. **Measured variables-** Measured variables are the observed variables in the study through questions intended for a clear and easy interpretation for the survey recipient. These variables are extracted directly from the data and serves as the building blocks for the structure of a Structural Equation Model.
2. **Latent variables-** Latent constructs or variables are defined as the variables which are unobserved in a study but are critical to the research and provide an underlying construct or idea from the data. These variables are inferred through a set of measured variables using the process of factor analysis.

All analysis was performed using R programming and software environment (*26*).

Factor Analysis

Factor analysis is the process of analyzing and extracting factors from multivariate data systems. It is based on the theory of common factors, which identifies a common factor as an internal attribute which affects a set of measured variables in a way which can provide explanation to the variances and covariances of these variables in a structural manner. It relates common factor to an underlying construct which is unobserved but attributes to the results obtained from the measured indicators. It is primarily based on the correlation and covariance matrices of the measured variables and helps in identifying internal critical constructs which cannot bet easily measured directly. This research uses two aspects of factor analysis- Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA).

Structural Equation Model

The inclusion of Structural Equation Model (SEM) commenced in the later part of the 20th century with especially with the use of latent variables in choice modelling which was facilitated by Ben Akiva (2002) that helped in providing another path to study traveler linked decisions (*27*). SEM is an example of second generation data analysis techniques which enables to answer a set of interrelated questions in a single, comprehensive and systematic manner in contrary to most first-generation techniques (*28*). Methods such as Linear regression, Logit and Probit models, ANOVA etc. only allows for examining a single route of links between the dependent and independent variables even in the case of an existing relationship between two sets of dependent variables. SEM, by using its latent construct theory and measurement errors overcomes this problem.

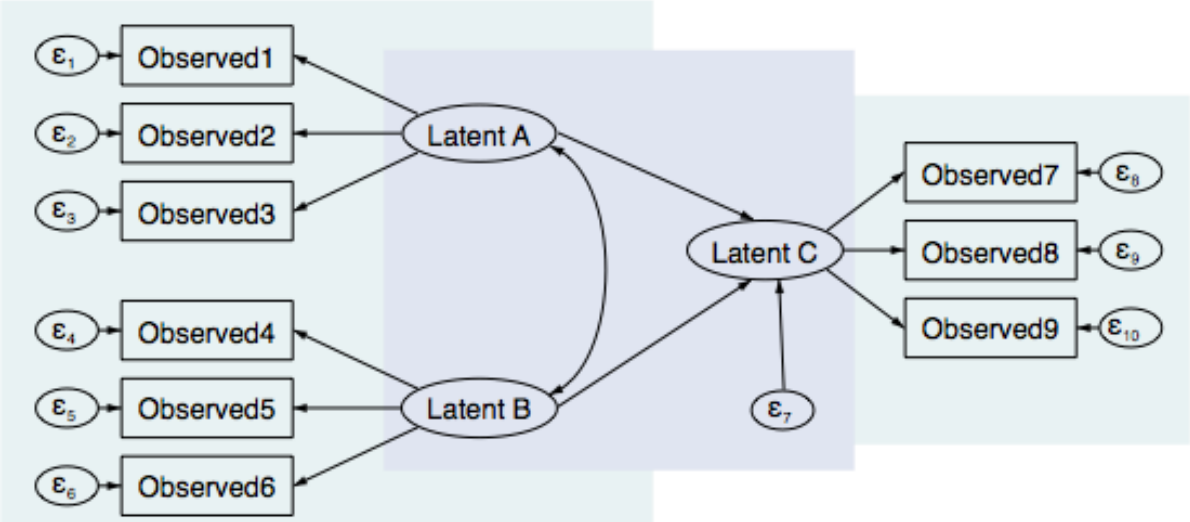

Figure 1 Simple SEM model with 3 latent factors and 9 observed variables

A standard SEM model consists of a simultaneous set of relationships between the observed-latent variables, latent-latent variables and observed-observed variables. It comprises of a measurement model which defines the latent constructs from the observed variables and a structural model which deals with relationships between the latent constructs. Figure 1 shows a simple SEM measurement model with three latent and nine observed variables (3 each), where ε_i denotes the measurement error for each observed variable. The individual structure of each latent variable denotes their factor relationship with each of the three observed variables with a two-sided arrow for correlation among themselves. Whereas, the directed arrows from latent variable A and B signifies the structural relationship of the two variables with the variable C, implying the regression of variable C by A and B respectively.

Goodness of fit Indices

Goodness of fit for an SEM model has often been a topic of discussion among the researchers due to its relative nature and complex set of relationships. The past literature suggested reporting more than one kind of fitness index to present an overall fit of the model and account for any biases (*29*, *30*). Hence, a combination of fit indices were used to evaluate the differences between the sample covariance matrix and the implied covariance matrix.

Root Mean Square of Approximation (RMSEA)- RMSEA tells about the quality of fit of the parameter estimates with that of the population covariance matrix (*31*). It is an absolute index of fit and values less than 0.7 and close to 0.6 represents an acceptable model (*32*, *33*).

Normed Chi- square (χ^2/df)- Standard chi-square statistic tends to be affected by the sample size and the multivariate normality assumption and as such the ratio of chi-square (χ^2) to the degrees of freedom (df) is used (*34*). A cut-off ratio of 3 is considered acceptable (*35*).

Standardized Root Mean Square Residual (SRMR)- SRMR is a standardized version of the difference in residuals of the sample and hypothesized model covariance matrices. It accounts for the different scale levels of indicators in the model. Generally, a cut-off of 0.08 is deemed acceptable for this index (*32*).

Comparative Fit Index (CFI)- A CFI presents a revised form of the Normed Fit Index (NFI) which accounts for the underestimation if fit in small samples. It ranges from 0 to 1 and a value close to 0.9 or greater is an indication of acceptable fit (*36*).

CHAPTER IV

DATA

Data

Data used in this study was collected using a postal and web-based survey called National Community Livability Survey. This survey was administered with a purpose to examine the role of livability in the context of transportation and how it affects the people's lives and their travel decisions. This was done by incorporating questions based on the six principles of livability (USDOT & Gough, 2015). Initially, the study was focused on exploring the role of transit and livability particularly in rural communities. Later, it was expanded to incorporate all types of communities- ranging from rural, sub-urban to more urban and compact neighborhoods. Overall, the survey instrument had 55 questions including open-ended questions among which 9 were specifically for transit users. This study is focused on the livability and mode choice related variables, therefore does not includes any discussion for the remaining questions.

The scope of the survey involved all 4 regions of the United States- Northeast, Midwest, South and West (U.S. Census Bureau). Further, the regions were further divided into divisions and Rural Urban continuums for sampling purposes. Population was sampled using a stratified sampling design which involved sampling from each region, division and Rural Urban Continuum codes (*37*). Addresses were identified based on the age and gender characteristics for each survey recipient in a stratum. The age group was divided into three classes- 18-44 years, 45-64 years and, 65 and above for both men and women respectively. Every survey consisted of a unique passcode

to enable the recipient for using web-based response option. The passcodes served as a reliable and convenient tool to ensure respondent authenticity.

Data Cleaning and post- processing

The survey resulted in 994 complete responses after cleaning for invalid and blank responses. There was an imbalance between the Census population distribution for age and gender groups of the individual strata and the responses received. To account for this imbalance, a post-stratification sampling weight matrix was created from the Census distribution and applied to each individual response using the method below-

$$\text{Post} - \text{stratification weight} = \frac{\text{Proportion of population}}{\text{Proportion of Sample}}$$

Table 1 shows the survey weights for the first strata. Similarly, weights for other Region, Division and RurUrban Continuum were calculated for the sample.

Table 1 Example of survey weights for the first strata

SAMPLING DISTRIBUTION								
Region	Div	Rururban	**F, 18-44**	**F, 45-64**	**F, 65+**	**M, 18-44**	**M, 45-64**	**M, 65+**
1	1	1	22%	22%	0%	11%	33%	11%
POPULATION DISTRIBUTION								
1	1	1	23%	18%	11%	23%	17%	8%
POST-STRATIFICATION WEIGHTS								
1	1	1	1.047	0.82	-	2.06	0.51	0.70

Specific age-gender groups had no responses and hence no weights were calculated for those cases.

Preliminary analysis

This section talks about the preliminary analysis conducted in an attempt to identify the relevant variables for our research by descriptive statistics and visual judgement. No specific variables were

eliminated based on this analysis albeit comparisons were made for relative importance of variables for further detailed analysis.

One of the purposes of this research was to study the effect of livability indicators on the automobile mode choice. Respondents were asked to answer questions related to factors of community livability in two ways- Rate the importance of each livability factor and rate the quality of each livability factor. Two different questions were used to investigate the aforementioned aspects of livability. Since each question was asked in the context of how they impact the community livability, they are termed as livability variables in this study. Each question had a 5-point Likert scale to measure the responses ranging from 1-Not Important/Very poor to 5-Very Important/Very good. A total of 14 factors were present in each question. Table 2 shows the recipient responses for the importance of each factor divided among the five categories on the Likert scale. Looking at the first question about the importance of each factor, it was observed that the responses were more inclined towards higher importance for most of the factors. A considerable proportion of moderately important scores was observed for Cultural Institutions, Shopping and Entertainment options, Parks and recreations options, and Weather factors.

Table 2 Responses for importance of each factor to community livability

	Not Important	Somewhat Important	Moderately Important	Important	Very Important
Available jobs	1.1%	1.1%	5.6%	27.7%	64.4%
Affordable transportation options	5.5%	9.2%	19.9%	32.0%	33.4%
Cultural Institutions	6.8%	13.2%	33.5%	31.1%	15.5%
Quality Healthcare	0.8%	1.1%	5.5%	27.4%	65.1%
Affordable Housing	1.3%	1.7%	8.9%	31.9%	56.1%
Quality public schools	2.4%	1.4%	7.0%	23.7%	65.4%
Overall cost of living	0.4%	1.0%	9.9%	39.0%	49.7%
Shopping and entertainment options	1.8%	9.2%	38.0%	35.3%	15.6%
Parks and recreational facilities	1.3%	8.3%	34.2%	35.9%	20.3%
Weather	3.9%	12.5%	33.0%	34.9%	15.8%
Clean environment	0.6%	1.5%	13.0%	40.7%	44.2%
Low crime	0.2%	1.1%	6.4%	31.1%	61.2%
Sense of community	1.3%	6.8%	23.2%	40.6%	28.1%
Traffic safety	0.7%	5.4%	19.6%	41.1%	33.2%

Respondents were then asked to rate the quality of the same factors as asked in Q1 of the survey. Table 3 shows the responses divided among the 5 categories like the one obtained in Table 2. A descriptive analysis showed a more uniform distribution among the categories of the scale.

Table 3 Responses for rating each factor in the community

	Very Poor	Poor	Moderate	Good	Very Good
Available jobs	9.7%	29.2%	32.3%	22.6%	6.2%
Affordable transportation options	15.1%	28.3%	33.7%	17.9%	5.1%
Cultural Institutions	11.2%	20.3%	40.0%	20.6%	7.9%
Quality Healthcare	4.7%	11.8%	31.3%	33.3%	18.9%
Affordable Housing	6.8%	20.1%	38.2%	25.4%	9.5%
Quality public schools	4.0%	10.4%	30.4%	36.8%	18.4%
Overall cost of living	4.4%	12.1%	39.9%	33.5%	10.1%
Shopping and entertainment options	12.6%	24.0%	34.8%	20.6%	7.9%
Parks and recreational facilities	4.4%	9.9%	33.0%	34.0%	18.7%
Weather	2.2%	4.2%	40.2%	41.4%	12.0%
Clean environment	1.4%	5.6%	31.2%	41.4%	20.4%
Low crime	2.7%	10.8%	31.6%	35.5%	19.4%
Sense of community	2.8%	9.0%	34.8%	35.8%	17.6%
Traffic safety	2.1%	6.5%	32.2%	44.4%	14.8%

The questionnaire also consisted of questions related to the transportation aspect of livability. They were asked in a similar way as the livability factors mentioned earlier. Figure 2 shows the distribution of responses for each factor. It is observed that all factors have a uniform like distribution except for the Roads in good condition factor, which is skewed towards important scale.

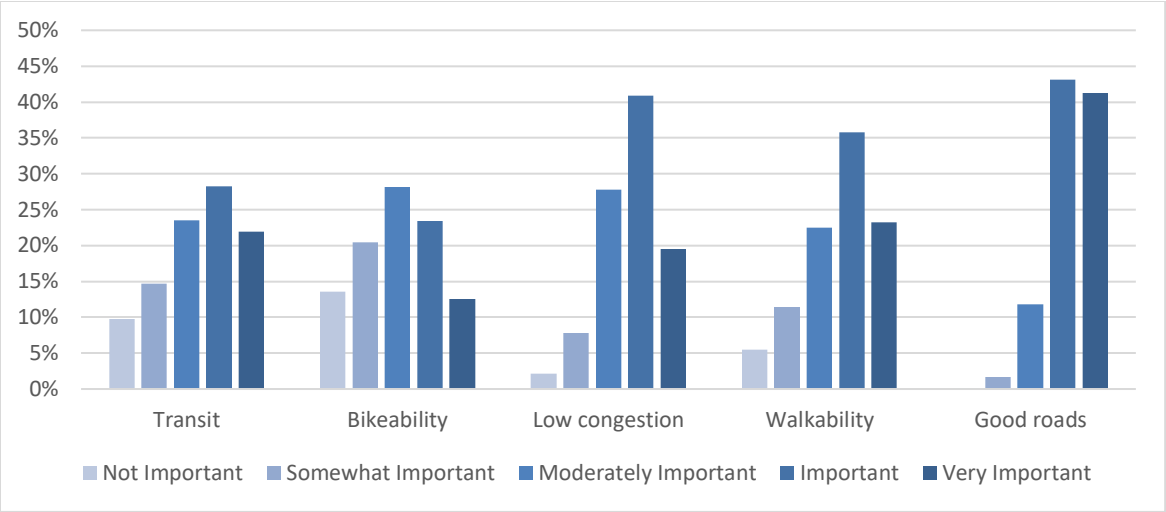

Figure 2 Response distribution for importance of each transportation aspect*

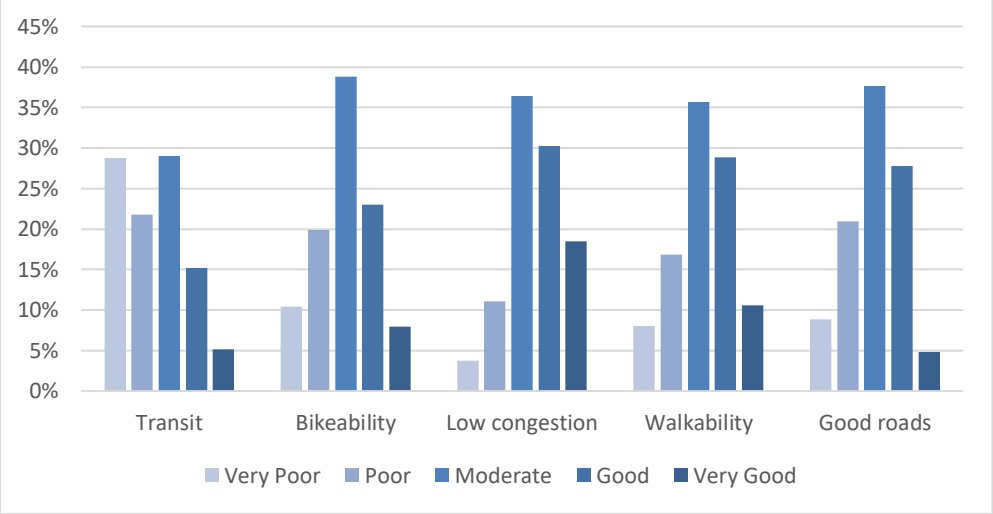

Figure 3 Response distribution for rated quality of transportation aspect*

*: Transit= Public Transit Services, Low congestion = Low traffic congestion, Walkability = Walkability/Accessibility, Good roads = Roads in good condition

Figure 3 shows the rated responses for each aspect of transportation in the survey. Closer look on the distribution suggests an anomaly for the quality of Public Transit services which is skewed towards poor quality. Other factors are mostly on moderate to good scale.

Among the variables reported in both the tables, Table 2 measures the importance attributed to each factor by the respondent while Table 3 is indicative of the perceived quality of the individual factors of livability in the survey. This objective of this study is to explore direct and indirect relationships between livability and mode choice. Since, Table 3 presents an idea of the quality of livability from the user's perspective, these variables are chosen for further analysis. The importance of transportation aspects is also considered valuable to the study. Hence, based on the preliminary analysis and response distribution for the factors presented, variables are selected.

CHAPTER V

ANALYSIS

Exploratory Factor Analysis

An Exploratory Factor Analysis (EFA) was used on the livability variables which were identified as important in the preliminary analysis of the data (Table 3). Since, livability variables were hypothesized to have some underlying constructs, an EFA allowed to validate and explore the nature of that relationship. It also facilitated the development of a theoretical measurement model for confirmatory factor analysis in SEM which is discussed in the later part of this chapter. The process of EFA consists of first identifying the number of factors to be extracted and then the loadings of the extracted factors on each of the measured variables. A factor loading signifies the amount of covariance of the latent variables explained by each individual measured variable. To conduct an EFA, the psych package in R was used (*38*).

The number of latent variables (factors in EFA) to be extracted was decided based on parallel scree plots obtained from "fa.parallel" function of the psych package, shown in Figure 4. Based on the results obtained, it was observed that 4 latent variables would better explain the measured variables. With the fa function, an EFA was obtained for the livability variables with 4 extracted latent variables using 'obliquemin' rotation and 'wls' extraction method with polychoric correlations. Both rotation and extraction methods were selected based on the given ordinal set of data and the assumption of correlations between the latent variables (*39*).

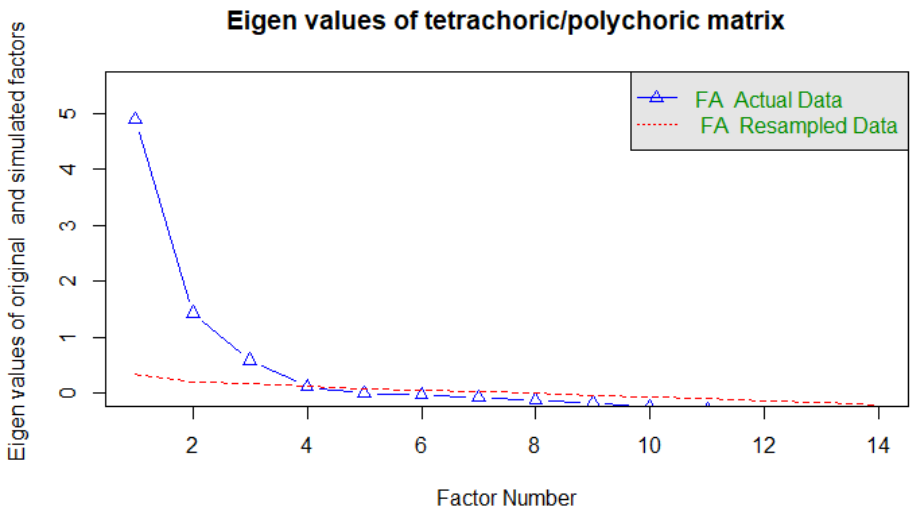

Figure 4 Parallel analysis scree plot for EFA

Table 4 shows the significant factor loadings obtained from the EFA on livability variables. To eliminate the insignificant factor loadings, a cutoff of 0.5 has been recommended in the literature and hence, was used in this analysis. It is to be noted that the latent variables and factor loadings obtained from this analysis is only indicative of the presence of a factor model and needs to be validated using a CFA for the measurement model. Highlights from the results suggest a potential services construct measuring available jobs, healthcare, cultural institutions and affordable transportation, among others. Also, the nature of the community measured variables like sense of community, low crime, clean environment and traffic safety. The use of a cutoff value helped in obtaining a simple structure in which each measured variable loads onto only one factor. Overall, the results from the analysis indicated a presence of 4 underlying factors which were then further evaluated for factor loadings and goodness of fit indices. This factor model confirmed the proposed hypothesis of common factors and served as a stepping stone for the measurement model.

Table 4 EFA results for 14 variables (TLI= 0.956, RMSEA= 0.051)

Measured variables	**Factor1**	**Factor2**	**Factor3**	**Factor4**
Available jobs	0.736			
Affordable transportation options	0.721			
Cultural Institutions	0.774			
Quality Healthcare	0.582			
Affordable Housing			0.763	
Quality public schools				
Overall cost of living			0.835	
Shopping and entertainment options	0.723			
Parks and recreational facilities	0.570			
Weather				0.995
Clean environment		0.669		
Low crime		0.845		
Sense of community		0.578		
Traffic safety		0.661		

The second part of the analysis consisted of developing a Structural Equation Model (SEM) for validating the results obtained from EFA along with studying and quantifying the effects of the selected constructs and variables.

Structural Equation Model (SEM)

This section involved the use of SEM for evaluating and assessing the relationships between variables selected from the previous analyses. Based on the data and the survey design, two methods were available for estimation- Maximum Likelihood(ML) and Diagonally Weighted Least Squares. Since, the data was ordinal in nature and presented departures from multivariate normality, a robust version of ML (MLR) was used because of its performance for samples under

1000 and very less degree of dependency on multivariate normality assumption. MLR used a sandwich-type estimator to correct standard error estimates obtained under normality assumption (*40*). Also, the model used weighted data which could be incorporated by MLR estimator in the "lavaan.survey" package used for the model formulation (*41–43*).

A Structural Equation Model consists of two sub-models-

1. **Measurement model**- The estimation of the structure of latent variables hypothesized from the exploratory factor analysis is conducted using the Confirmatory Factor Analysis (CFA). After validation from model goodness-of-fit indices and theoretical justification, the model is termed as a measurement model.
2. **Structural model-** A structural model in SEM deals with the regression part of the analysis. It involves directed relationships between latent-latent variables and latent-observed variables. Using the latent variables of the measurement model obtained along with other user specified variables, a structural model was formed.

Measurement model

1. **Livability variables-**

   A CFA model was developed for the livability variables. Based on the EFA (Table 4), Quality public schools was deleted as it did not have any shared covariance with any latent factor so observed. Since, Weather represents a variable largely influenced by climatic conditions which is not directly impacted by any policies and also was the only variable in Factor 4 of the EFA, it was ruled out of the analysis. The remaining 12 variables were tested in the CFA model and assessed for a model fit.

Two CFA models- Model A (with three latent variables) and Model B (with four latent variables) were formulated (Table 5 and Table 6).

Table 5 Livability CFA Model A

Services	**Society**	**Living**
Available jobs	Sense of community	Affordable Housing
Quality Healthcare	Low crime	Cost of living
Affordable transportation options	Clean environment	
Cultural institutions	Traffic safety	
Shopping & Entertainment options		
Parks & Recreation facilities		

Table 6 Livability CFA Model B

Services	**Society**	**Living**	**Recreation**
Available jobs	Sense of community	Affordable Housing	Shopping & Entertainment options
Quality Healthcare	Low crime	Cost of living	Parks & Recreation facilities
Affordable transportation options	Clean environment		
Cultural institutions	Traffic safety		

Table 7 shows the goodness of fit for both models. It was observed that Model B had a better fit which consisted of 4 latent variables. Also, the parallel analysis (Figure 4) suggested the presence of four underlying factors. Hence, Model B was selected as the livability measurement model for the SEM model.

Table 7 Fit indices for Livability CFA models

Indices	**Model A**	**Model B**
Model fit test statistic	438.79	418.37
Degrees of freedom	153	153
Normed chi-square (Test statistic/df)	2.87	2.73
Robust RMSEA	0.06	0.06
SRMR	0.054	0.053
Robust Comparative Fit Index (CFI)	0.92	0.93

Figure 5 shows the path diagram of the measurement model for the livability variables.

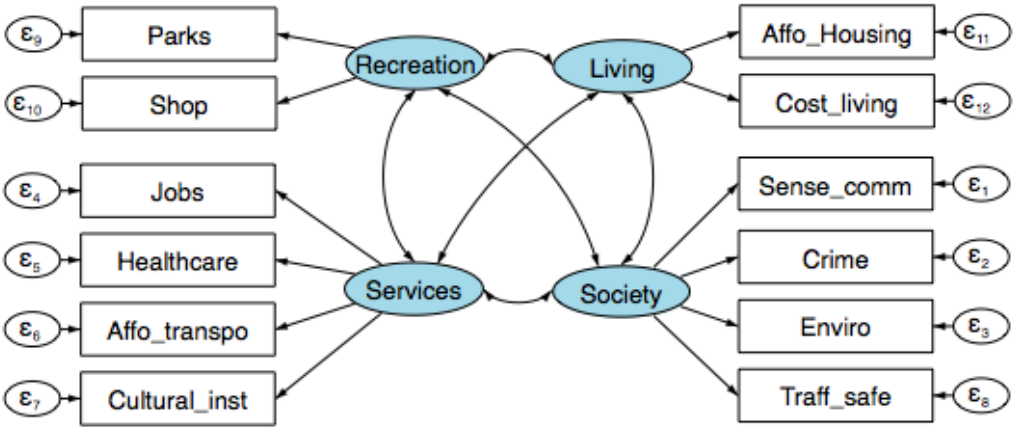

Figure 5 Measurement model for livability variables

2. Alternative transportation importance

From the transportation aspect variables (Figure 2) which were found to be equally important in the preliminary analysis, a structure was hypothesized based on the nature of the transportation measured by the respective variables and a latent variable called Alternative transportation was formulated (Figure 6).

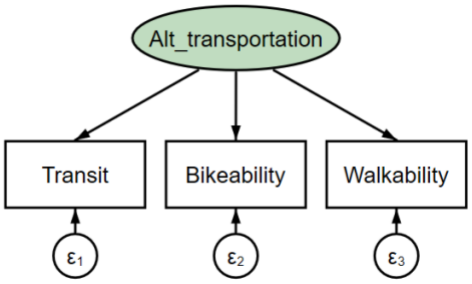

Figure 6 Latent factor model for Alternative transportation importance

The three variables measuring the importance of non-motorized transportation in the survey- Public transit services, Bikeability and Walkability/Accessibility, were chosen as

they represented the importance of other modes of transportation. These variables proved to be relevant in providing a perspective into car preference.

3. Car choice

The central focus of this study was to measure the dependency of car choice tendency with other factors. For that purpose, instead of considering a single variable as a manifestation of driving behavior, a latent variable called "Car choice" was identified with the consideration of three observed variables which represented the preference of car as a travel mode (Figure 7).

- **Drive_freq**- This variable was a dummy variable created based on the question: "Think about your trips in a typical week…how many days do you use each mode?". Among the modes asked, driving myself was selected for driving behavior.
- **Future_choice**- This variable was based on the question: "Which of the following statements most likely describes your future vehicle ownership?". This variable suggested a possible relation of future vehicle preferences to current driving choice.
- **Vehicle_count**- This variable identified the number of working vehicles available in a household as answered by the respondent. Since, the availability of vehicles is logically related to driving choice, the inclusion of this variable was intuitive.

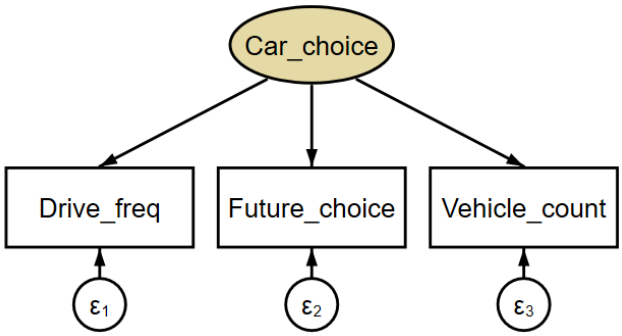

Figure 7 Latent factor model for Car choice variable

The four livability latent variables- Services, Society, Recreation and Living, Alternative Transportation importance and the dependent variable Car choice together constituted the measurement model of the SEM analysis.

Structural model

The second part of the SEM dealt with establishing and verifying the associations between the variables. The latent variables obtained from the measurement model were extensively used for establishing relationships between the constructs. Demographic variables used were- Age, Household size and Household Income. Modification indices generated from a standard SEM analysis were used to make appropriate local modifications to the initial model for obtaining an optimum set of relationships having sound theoretical justifications(*29*, *30*). After four iterations, the model was finalized based on significance. The model fit remained consistent in the process. Figure 8, Figure 9, Figure 10 and Figure 11 shows the model iteration path diagrams.

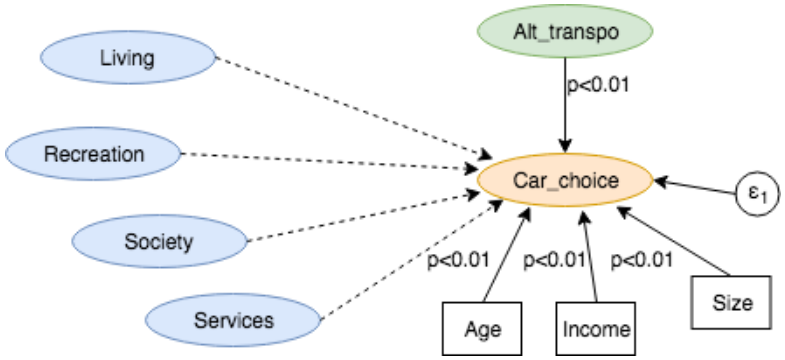

Figure 8 Structural Model- iteration 1

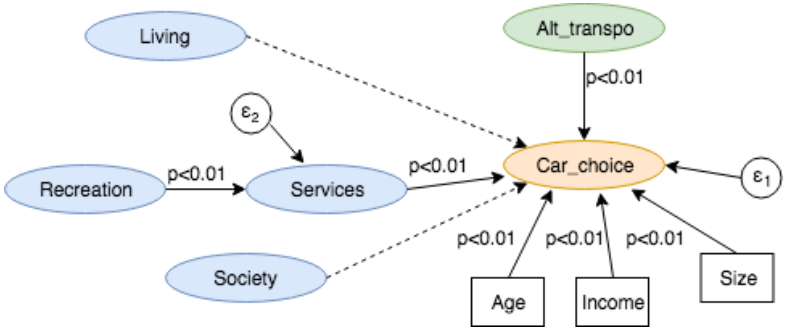

Figure 9 Structural Model- iteration 2

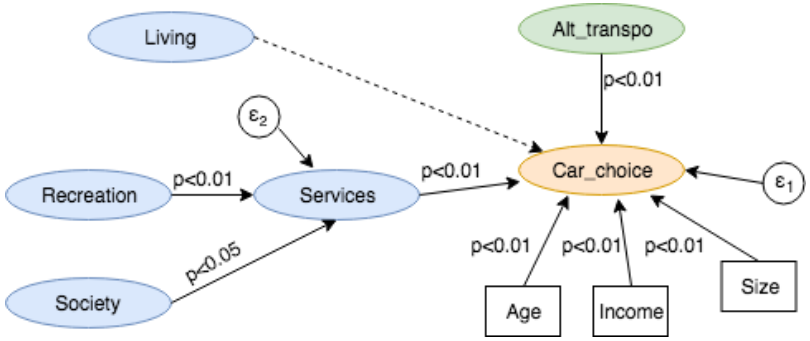

Figure 10 Structural Model- iteration 3

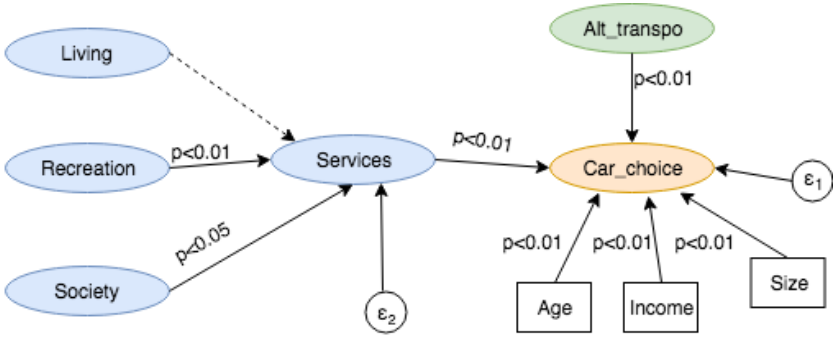

Figure 11 Structural Model- iteration 4

Iteration 1 did not give any significant effects from the four livability variables (Figure 8). Additionally, iteration 2 and 3 provided significant effects of Recreation and Society on the Services variable. Among iteration 3 and iteration 4, iteration 4 (Figure 11) was chosen as it provided an overall better fit of the model.

Services acted as a complete mediating variable between the other livability variables and the dependent variable of car choice. A mediating relationship accounts for the indirect effect of an independent variable on the dependent variable (*44*, *45*). Indirect effects are dependent on the existence of a mediating variable. Age was recoded as having three categories: 18-44, 45-25 64 and 65+ groups (originally sampled under same groups). Income was also recoded into 4 categories: Less than 15000, 15000-49999, 50000-99999 and 100000 or above while the 6 categories of Household size were retained as is in the data. Results are shown in the next chapter.

Multigroup analysis

The objective of a multi-group analysis was to study the moderating effects of the chosen variables across its groups. In other words, path estimates are compared for invariance across the groups, which is also known as structural invariance. Figure 12 shows an overview of the multi-group analysis.

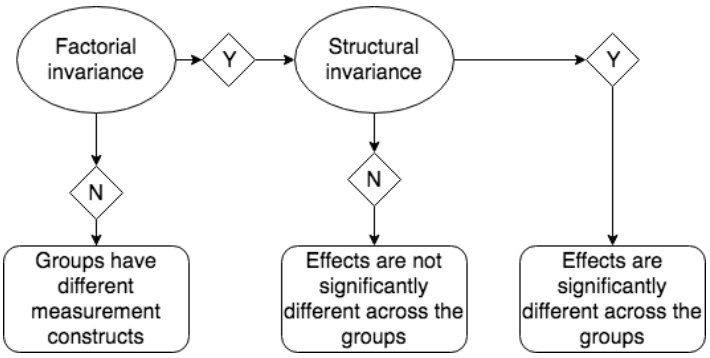

Figure 12 Multi-group analysis flowchart

Although, to be able to test for structural invariance, an invariance for factor loadings, factorial invariance has to be evaluated first to ensure the comparability of the categories with each other. For this process, a chi-square difference test for factor loadings is evaluated. It tests a constrained factor loadings model having equal loadings across all groups against a model with unconstrained parameters. If the hypothesis for invariance cannot be rejected, the model is established as having factorial invariance for the group. On the other hand, a rejected hypothesis indicates different units of measurement across the groups which would ultimately make the structural invariance invalid. After establishing factorial variance, a structural invariance test is performed by fixing the path estimates (structural coefficients) for each group. In this study, three variables related to transit availability, working status and gender were chosen for the multi-group analysis.

Transit Availability

The data was analyzed based on the question "Is Transit currently available to residents of your community?- A)Yes B)No C)Not Sure". Respondents who answered option B or C were placed under the group on "Transit Not available" while the ones who answered option A constituted the "Transit Available" group.

Table 8 Factorial invariance chi-square difference test- Transit availability

	Df	**AIC**	**BIC**	**Chisq**	**Chisq diff**	**Df diff**	**Pr(>Chisq)**
Unconstrained	344	39535	40189	1050.8			
Constrained	356	39523	40122	1062.9	8.2774	12	0.7631

From Table 8, it can be seen that the chi-square test failed to reject the null hypothesis of factorial invariance. Hence, a structural invariance test was also performed. This test rejected the structural invariance between the two groups and indicated different path effects for people with and without transit availability (Table 9) . Since, this difference applied to the whole model, all individual effects were deemed as being significantly different for interpretation at the appropriate significance level.

Table 9 Scaled chi-square difference test for structural invariance- Transit availability

MODEL	**Df**	**AIC**	**BIC**	**Chisq**	**Chisq diff**	**Df diff**	**Pr(>Chisq)**
Unconstrained	344	39535	40189	1050.8			
Constrained	352	39560	40178	1092.0	27.397	8	0.0006037 ***

Working Status

The data was analyzed based on the question "Which of the following best describes your current employment status?- Employed Full-time, Employed Part-time, Student, Retired, Unable to work due to a disability, Not employed, looking for work". For this analysis, all those who answered employed either full-time or part-time, were placed in the "Working" group. All the others were placed under the "Non-working" group. Responses with ambiguous or conflicting answers were discarded from this analysis.

Table 10 Factorial invariance chi-square difference test- Working status

	Df	AIC	BIC	Chisq	Chisq diff	Df diff	Pr(>Chisq)
Unconstrained	344	39398	40053	1051.3			
Constrained	356	39397	39996	1073.5	14.568	12	0.2659

The factorial invariance testing validated invariance across the two groups (Table 10). Following this, a structural invariance testing was also performed to check the difference in path coefficients across the working and non-working group.

From Table 11, it is clear that the two groups have significantly different structural relationships.

Table 11 Scaled chi-square difference test for structural invariance- Working status

MODEL	Df	AIC	BIC	Chisq	Chisq diff	Df diff	Pr(>Chisq)
Unconstrained	344	39398	40053	1051.3			
Constrained	352	39410	40027	1078.7	18.794	8	0.016 **

Gender

The data was analyzed based on the gender of the respondent, as reported in the survey. Two groups- Female and Male, were tested first for factorial invariance.

Table 12 Factorial invariance chi-square difference test- Gender

	Df	AIC	BIC	Chisq	Chisq diff	Df diff	Pr(>Chisq)
Unconstrained	344	39774	40428	1098.7			
Constrained	356	39786	40385	1135.0	22.763	12	0.0298*

As Table 12 suggests, the null hypothesis for factorial invariance was rejected which indicated a non-applicability of the same model parameters across the two groups of Gender. This would mean that the measurement model has significantly different estimates for the two groups and hence the difference between their path coefficients was not evaluated.

CHAPTER VI

RESULTS

Measurement model

The latent factor models hypothesized in the previous chapter were used to construct a single combined measurement model. This was achieved with the help of "lavaan.survey" package in R (*43*). Table 13 shows the Unstandardized and standardized estimates of factor loadings for each of the six latent variables in the model. As seen from the table, all estimates were found to be significant at 99% confidence interval.

Table 13 Factor loadings for the measurement model

	Unstandardized (B)	**P(>|z|)**	**Standardized (β)**
Alt_transportation =~			
Transit	1		0.926
Bike	0.691	0	0.655
Walk	0.672	0	0.666
Society =~			
Sense_comm	1		0.746
Crime	0.968	0	0.726
Enviro	0.763	0	0.617
Traff_safe	0.857	0	0.696
Services =~			
Jobs	1		0.735
Healthcare	0.913	0	0.665
Aff_transpo	0.956	0	0.677
Cultural_inst	1.056	0	0.752
Car_choice =~			
Drive	1		0.321
Vehicles	2.773	0	0.902
Future_choice	1.81	0	0.401
Living =~			
Affo_Housing	1		0.711

Table 13 continued

	Unstandardized (B)	**P(>|z|)**	**Standardized (β)**
Cost_living	1.211	0	0.918
Recreation =~			
Parks	1		0.647
Shop	1.303	0	0.765

After assessing the measurement model, structural relationships were evaluated and tested for significance.

Base Model

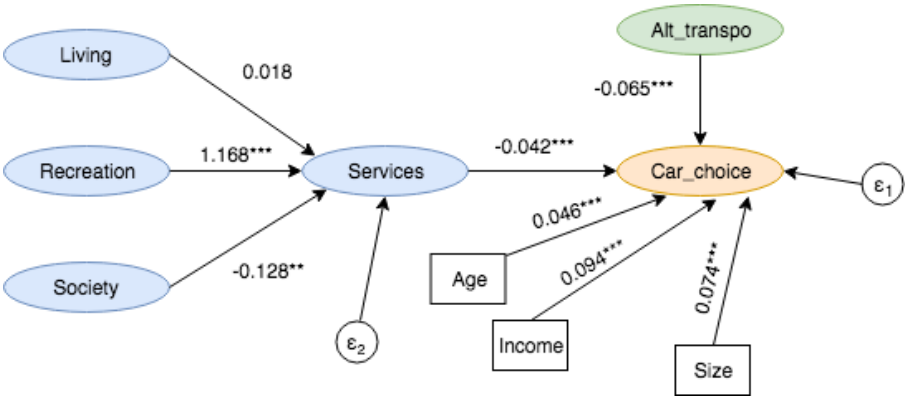

Figure 13 Base model with unstandardized direct effects

The unstandardized direct effects obtained from the analysis for the base model are shown in Figure 13. The values depict the magnitude of the direct effects obtained from the model evaluation without any moderating effects. Table 14 shows the standardized and unstandardized structural coefficients. All direct relationships were found to be significant at $p<0.01$ while the indirect effect of recreation was significant at $p<0.05$.

Table 14 Total standardized and unstandardized effects for base model

	Unstandardized		**Standardized**	
	Services	**Car Choice**	**Services**	**Car Choice**
Living	0.018	-0.001	0.017	-0.002
Recreation	1.168***	-0.049***	1.025***	-0.132***
Society	-0.128**	0.005	-0.124**	0.016
Alt Transportation		-0.065***		-0.305***
Services		-0.042***		-0.129***
Income_recoded		0.094***		0.341***
Size		0.074***		0.383***
Age_recoded		0.046***		0.139***

****: p<0.01, **: p<0.05*

In the base model, the Recreation indirect effect and all direct effects were significant at p<0.01. The following effects were observed-

- Services showed a negative effect which meant that a better quality of services would work in favor of reducing car preference for the users.
- Recreation had a negative indirect effect on car choice through the mediating Services variable, implying that improving the quality of recreation facilities like parks and shopping centers would also reduce the inclination towards personal vehicles in the presence of better services.
- The importance of alternative transportation also showed a negative effect which implies that an increased importance of alternative transportation modes reduces preference for automobiles.
- Income and household size seemed to have an approximately equal positive effect which suggests that higher income and larger sized households are more inclined towards choosing vehicles as a travel mode.

- Age was also positively related though having a lesser effect in magnitude than other demographic variables, implying that older people prefer cars more than their younger counterparts.

Multi-group analysis

A multi-group analysis of the data revealed the differences and influences of moderating variables on the SEM model. Two variables- Transit Availability and Working Status demonstrated different effects.

Transit Availability model

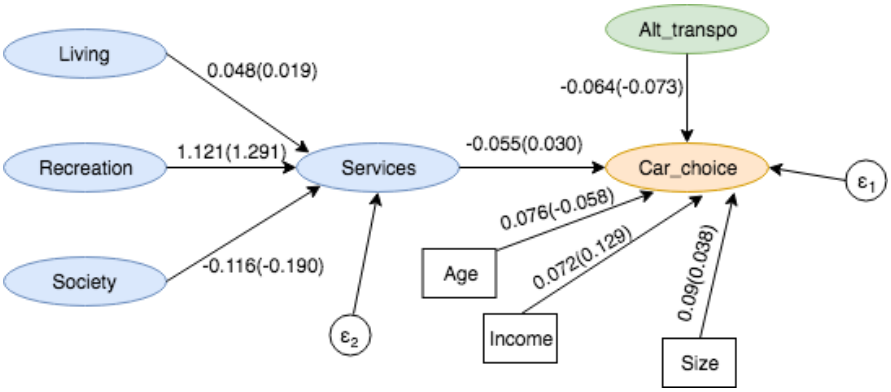

Figure 14 Unstandardized direct effects for transit available and not available groups

From the multi-group analysis based on transit availability variable, the unstandardized direct effects observed are shown in Figure 14. The effects in parentheses represents the "Transit Not Available group while the other represent "Transit Available' group. The direct and indirect effects are shown in

Table 15. All effects were significant at p<0.001 level. The following effects were observed-

- Services negatively affected the car choice for areas with transit availability and vice-versa for no transit areas. This indicated that having better services in the presence of transit facilities could discourage users for personal cars. Recreation had a similar indirect effect while Living and Society had minimal effect for both groups.
- The presence of transit does not seem to influence the effect of the importance of alternative transportation options too much.
- Higher income for no transit areas caused more inclination towards car when compared to transit available areas. A possible explanation could be the increased purchasing power and affordability for higher income people which would suggest increased reliance over personal vehicle.
- Individuals with greater family size and residing in transit available areas are bit more likely to prefer car in comparison to their no transit counterparts. This result seems counter-intuitive but may be attributed to the increased per capita cost of transit for larger households.
- As a person gets older, their preference for car increases in areas of transit availability while it decreases in areas with no transit.

Table 15 Total unstandardized effects for multi-group analysis-Transit Availability

	Transit available		**Transit not available**	
	Services	**Car Choice**	**Services**	**Car Choice**
Living	0.048	-0.003	0.019	0.001
Recreation	1.121	-0.062	1.291	0.039
Society	-0.116	0.006	-0.190	-0.006
Alt Transportation		-0.064		-0.073
Services		-0.055		0.030
Income_recoded		0.072		0.129

Table 15 continued

	Transit available		Transit not available	
	Services	**Car Choice**	**Services**	**Car Choice**
Size		0.09		0.038
Age_recoded		0.076		-0.058

Working status model

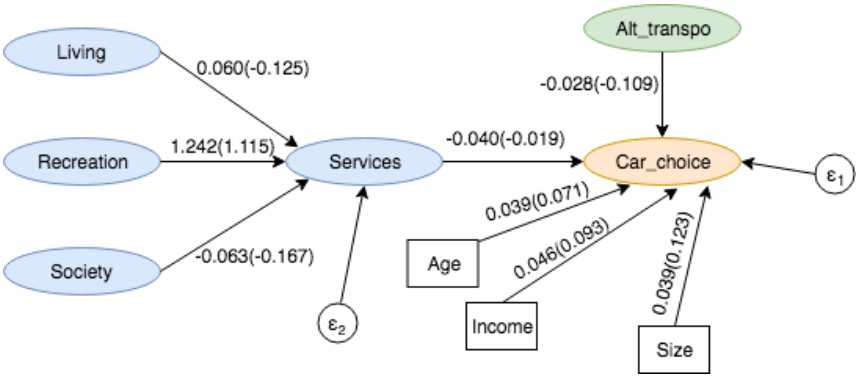

Figure 15 Unstandardized effects for working and non-working group

From the multi-group analysis of Working status group, the unstandardized effects obtained are shown in Figure 15. The effects in parentheses represent the "Non-Working" group while the other represents "Working" group. Table 16 represents the direct and indirect effects. All effects were significant at $p<0.016$ significance level. The following effects were observed-

- Better quality services seemed to discourage more working status people than the non-working people in their choice of personal mode of travel. Among other livability variables, Recreation also had more negative effect for the working class people while Living and Society had minimal effects.

- Higher importance given to alternative transportation options by non-working individuals highly discourages them towards personal vehicles as opposed to the working population.
- Non- working individuals with higher income are more likely to prefer a car than working individuals. Similar results were obtained for older non-working population.
- The results for household size indicated that as the size of a household increases, the non-working individuals tend to be more encouraged towards personal mode of travel.

Table 16 Total unstandardized effects for multi-group analysis-Working status

	Working		**Non-Working**	
	Services	**Car Choice**	**Services**	**Car Choice**
Living	0.060	-0.002	-0.125	0.002
Recreation	1.242	-0.050	1.115	-0.021
Society	-0.063	0.003	-0.167	0.003
Alt Transportation		-0.028		-0.109
Services		-0.040		-0.019
Income_recoded		0.046		0.093
Size		0.039		0.123
Age_recoded		0.039		0.071

Goodness of Fit for the model

A goodness of fit for the model was evaluated based on the indices discussed in the methodology chapter. Table 17 shows all the fit indices for the base model and the two multi-group models. Although, multi-group analysis was based on the same structural model, the fit for each model was different due to different observations per group.

Table 17 Goodness of fit

Indices	**Base**	**Transit Availability**	**Working Status**
Model fit test statistic	432.31	611.18	628.13
Degrees of freedom	172	344	344

Table 17 continued

Indices	**Base**	**Transit Availability**	**Working Status**
Test statistic/df	2.51	1.78	1.83
Robust RMSEA	0.061	0.06	0.061
SRMR	0.07	0.076	0.08
Robust Comparative Fit Index (CFI)	0.908	0.908	0.91

The base model (Figure 13) indicated goodness of fit indices within the cutoff ranges mentioned in the previous chapter. Furthermore, the same model could be applied to the transit available (Figure 14) and working group (Figure 15) multi-group models with the same degree of fitness. Hence, the models were accepted for the analysis and relevant conclusions were drawn.

CHAPTER VII

CONCLUSION AND DISCUSSION

Conclusion

This research used a national level postal survey to study responses based on a selected set of questions. First, a preliminary and exploratory analysis was done to select the relevant questions and number of latent factors respectively. Later, an SEM model was developed based on the proposed hypothesis and analytical observations obtained from the R program to study the effect of latent-only variables and latent-demographic variables on car choice. Additionally, a multi-group analysis for Transit Availability and Working Status was used to analyze their moderating effects. Moderating variables accounted for the change in the magnitude and sometimes the nature of an effect between the variables. All effects were considered significant after testing for overall model significance. Finally, a table for total effects was obtained for the variables and factors involved in the models.

The results suggested a range of effects for the variables involved in the models. Among the livability variables, the indirect effect of Living and Society were minimal and hence no references were made from them. The demographic variables, Household Income and Household Size showed positive effects for the car choice variables which implies that people in higher categories of income and household size would prefer more automobiles. Other variables had different effects in the models and have been summarized below-

Recreation

- Without any moderating effects of other variables, an improvement in the quality of Recreation facilities could reduce the preference for personal vehicles as a travel mode.
- For areas with transit livability, an increase in the quality of Recreation would decrease the preference for automobiles. Whereas, people in areas with no transit would prefer more personal vehicles if the quality of Recreation facilities is improved.
- Improving the quality of Recreation would decrease the preference for automobiles for both working and non-working people. Although, the magnitude of the impact would be more for the Working people group.

Services

- Improving the quality of Services would result in lesser preference for personal vehicles.
- For transit available areas, improved quality of services would reduce the preference for automobiles whereas it would increase the preference in areas with no transit.
- Working Status- Working people are more likely not to prefer personal vehicles than the non-working people when the quality of Services is improved.

Alternative Transportation importance

- An increase in the importance of alternative modes of transportation would lead to a decrease in the preference for automobiles in the absence of any moderating effects of other variables.
- Transit seems to have no considerable impact on the relationship between alternative transportation importance and preference for vehicles.

- The increase in the importance of alternative modes would decrease the preference for personal vehicles more for the non-working group.

Age

- Without any moderating effects, increase in age would result in more preference for automobiles.
- Increasing age for people living in areas with no transit would lead to decrease in preference of automobiles whereas older people in areas with transit would prefer more personal vehicles.
- Older non-working people would have more preference for personal automobiles when compared to older working people.

Discussion

The results suggest that improving the quality of Recreation facilities would drive down the preference for automobiles except for areas with no transit availability. This oddity might be attributed to the impact of Recreation in the lives of people. It suggests that people place certain amount of importance to quality recreation and they would be more inclined to use their personal cars when the quality of such facilities is improved in the absence of transit. However, the presence of transit would help in reducing the preference for automobiles.

Improving the quality of Services would also help in reducing the preference for automobiles except for no transit areas. Similar to Recreation, the presence of transit is important to reduce car preference. Since, the quality of services is a critical part of a person's life, in order to utilize these services, they would make use of a convenient travel mode. In the absence of transit, they would therefore be more inclined to use personal vehicles to access those services.

A possible explanation of the results for the importance of alternative transportation would be the propensity of people who place more importance on modes other than automobile to use less cars. By creating polices aimed at improving the quality and awareness of other modes of transportation might be beneficial in increasing the importance of alternative modes of transportation. This would ultimately help in reducing the preference of automobiles for all groups of people.

The absence of transit for older people might affect their trip rates and could be the reason for their decreased preference for automobiles in no transit areas. On the other hand, their preference for automobiles in transit available areas might be attributed to unattractive or inaccessible transit services.

Study limitations

Although this study attempts to paint a comprehensive picture of travel mode choice, it has a few limitations in terms of its scope and approach. The SEM package used in the analysis was Lavaan which has its own limitations (*22*). Lavaan uses Maximum Likelihood method for SEM with complex survey design which assumes an underlying normal distribution for ordinal responses. To minimize this, only ordinal variables with robust measures of fit were used in this analysis. Transit availability was taken as 'Not available' even for answer choice of 'Not sure'. Hence, those responses denote an ignorant respondent although that would have minimum impact on this study as it had more to deal with respondent's perspective.

Benefits and future work

In today's world, travel mode decisions are considered as pivotal for all aspects of transportation. Planning, operations and even transportation infrastructure are driven by individual level travel

behavior. This study, by presenting a wider picture of how demographic factors of age, income and household size with the factors of livability and the importance of alternative modes of transportation can affect travel decisions, lays the groundwork for a deeper investigation into different perspectives of travel behavior. It talks about the inclination of a person towards choosing personal vehicle as a travel mode and how the surrounding factors of everyday life can influence it along with their individual characteristics. This would likely be useful for formulating policies directed towards specific demographics or perhaps improving rather unrelated factors like livability to influence transportation. It also establishes the many distinct effects of transit availability and working status of a person towards defining the ultimate outcome. Additionally, the use of latent variables for livability demonstrates the ability to treat and study various hypothesized measures of livability by a selected few meaningful constructs. Finally, as the literature suggests, this area of study is vast and car travel could be influenced by a multitude of other factors. A longitudinal SEM model might be a region of future research to study the changes before and after policy interventions. The scope of this study was limited to livability and selected demographic variables which might not give an exhaustive idea of the causal relations of personal vehicle as a travel mode choice with other factors.

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APPENDIX

START HERE

Think about the 1,000s of communities in America...

1. In your opinion, how important is each factor to community livability? *Check one per row.*

	Not important	Slightly important	Moderately important	Important	Very important
Available jobs	○	○	○	○	○
Affordable transportation options	○	○	○	○	○
Cultural institutions	○	○	○	○	○
Quality healthcare	○	○	○	○	○
Affordable housing	○	○	○	○	○
Quality public schools	○	○	○	○	○
Overall cost of living	○	○	○	○	○
Shopping and entertainment options	○	○	○	○	○
Parks and recreation facilities	○	○	○	○	○
Weather	○	○	○	○	○
Clean environment	○	○	○	○	○
Low crime	○	○	○	○	○
Sense of community	○	○	○	○	○
Traffic Safety	○	○	○	○	○

2. How important is each aspect of transportation to community livability? *Check one per row.*

	Not important	Slightly important	Moderately important	Important	Very important
Public transit services	○	○	○	○	○
Bikeability	○	○	○	○	○
Low traffic congestion	○	○	○	○	○
Walkability / accessibility	○	○	○	○	○
Roads in good condition	○	○	○	○	○

3. What ZIP code do you live in? _ _ _ _ _

4. How long have you lived in the community where you live now?

- ○ Less than 1 year
- ○ 1 to 5 years
- ○ 6 to 10 years
- ○ 11 to 20 years
- ○ More than 20 years

5. How satisfied are you with the quality-of-life in your community?

Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
○	○	○	○	○

CONTINUE ON BACK... ➘

Think about where you live now…

6. Rate the quality of each livability factor in your community right now: *Check one per row.*

	Very poor	Poor	Acceptable	Good	Very good
Available jobs	○	○	○	○	○
Affordable transportation options	○	○	○	○	○
Cultural institutions	○	○	○	○	○
Quality healthcare	○	○	○	○	○
Affordable housing	○	○	○	○	○
Quality public schools	○	○	○	○	○
Overall cost of living	○	○	○	○	○
Shopping and entertainment options	○	○	○	○	○
Parks and recreation facilities	○	○	○	○	○
Weather	○	○	○	○	○
Clean environment	○	○	○	○	○
Low crime	○	○	○	○	○
Sense of community	○	○	○	○	○
Traffic safety	○	○	○	○	○

7. Rate the quality of each aspect of transportation in your community right now: *Check one per row.*

	Very poor	Poor	Acceptable	Good	Very good
Public transit services	○	○	○	○	○
Bikeability	○	○	○	○	○
Low traffic congestion	○	○	○	○	○
Walkability / accessibility	○	○	○	○	○
Roads in good condition	○	○	○	○	○

People live on a wide variety of streets—from urban core downtowns streets to urban center streets to general urban streets to suburban streets to rural small town streets to natural/open-country streets.

8. Which of the following most closely describes the kind of street you live on?

- ○ **Urban core street** (downtown, high-rise/mid-rise housing units)
- ○ **Urban center street** (near downtown, multi-level housing units)
- ○ **General urban street** (single to multi-level buildings, townhomes/row houses/apartments/etc.)
- ○ **Suburban street** (mostly single-family houses or apartment buildings)
- ○ **Rural street** (small city/towns, typically single-family houses or small apartment buildings)
- ○ **Open-country/Natural area** (few houses, open-country mostly)

9. Which phrase best describes the way you define your community in terms of geographic size?

- ○ My community is **a part of my local neighborhood.**
- ○ My community is my **whole local neighborhood.**
- ○ My community is my **city.**
- ○ My community is my **county.**
- ○ My community is **all of the region I live in.**
- ○ Other: _____

CONTINUE ON PAGE 3 ➔

10. How much do you agree or disagree with the following statement?

"I can easily travel to places I need to go in my community using my current travel options."

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
○	○	○	○	○

11. Think about your trips in a typical week…how many days do you use each mode?

Check one per row.

	Not available	0 days	1 day	2-4 days	5 or more days
Walk (including using a mobility assistive device)	○	○	○	○	○
Personal bicycle	○	○	○	○	○
Bike share	○	○	○	○	○
Drive myself (alone in car, truck, motorcycle, scooter)	○	○	○	○	○
Carpool (traveling with other riders in a private car)	○	○	○	○	○
Public transit (e.g., rail, bus, ferry)	○	○	○	○	○
Vanpool (traveling with other riders in a van)	○	○	○	○	○
Taxi-cab (e.g., Yellow Cab)	○	○	○	○	○
Ride-sourcing (e.g., Uber, Lyft)	○	○	○	○	○
Car-share (e.g., Car2Go, ZipCar)	○	○	○	○	○

12. Is public transit currently available to residents of your community?

○ Yes ○ No ○ Not sure

13a. Have you used public transit in your community?

○ Yes ○ No

14. Do you know someone else who has used public transit in your community?

○ Yes ○ No

13b. If transit were available, how likely are you to use public transit for some of your trips?

Not likely ○ Somewhat likely ○ Very likely ○

SKIP TO QUESTION #17
(TOP OF NEXT PAGE)

15. Which mode(s) of public transit are available in your community?

Check all that apply.

- ☐ **Rail** (e.g., light rail, commuter rail, subway, etc.)
- ☐ **Local bus** (e.g., fixed, flexible, deviated, etc.)
- ☐ **Paratransit for people with disabilities**
- ☐ **Commuter bus** (e.g., express, park-and-ride, etc.)
- ☐ **Demand responsive transit** (e.g., dial-a-ride, etc.)
- ☐ **Intercity bus** (e.g., Greyhound, Megabus, etc.)
- ☐ **Ferry**
- ☐ **Other mode(s)**:

People use public transit to access a variety of services and amenities. We are interested in finding out if public transit can connect you with certain types of places.

16. If you chose to, could you ride public transit from near your residence to the following types of places? *Check one per row.*

Yes	No	*Not sure*	
○	○	○	**Grocery store or supermarket** (fresh fruit, vegetables, bread, meat)
○	○	○	**Personal services** (bank, hair/nail salon, laundromat)
○	○	○	**Other retail shopping** (clothes, pharmacy, household goods)
○	○	○	**Recreation and Entertainment** (parks, movies, museums, live theatre)
○	○	○	**Health care facility** (doctor's office, urgent care, hospital)

CONTINUE ON BACK…

17. If you are able, and chose to, could you walk from your residence to the following types of places? *Check one per row.*

	Yes	No	Not sure
Grocery store or supermarket (fresh fruit, vegetables, bread, meat)	○	○	○
Personal services (bank, hair/nail salon, laundromat)	○	○	○
Other retail shopping (clothes, pharmacy, household goods)	○	○	○
Recreation and Entertainment (parks, movies, museums, live theatre)	○	○	○
Health care facility (doctor's office, urgent care, hospital)	○	○	○

18. How much do you agree or disagree with the following statement?

"It is important for public transit to be available to my community's residents."

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
○	○	○	○	○

19. Why is it important to have public transit service in your community? *Check all that apply.*

- ☐ Because walk access to destinations is difficult in my community
- ☐ Because bike access to destinations is difficult in my community
- ☐ Transit is an option for seniors or people with disabilities
- ☐ Transit is an option for those who choose not to drive
- ☐ Transit is an option for saving on the cost of transportation
- ☐ Transit complements other travel modes, such as walking or biking
- ☐ Transit reduces energy consumption or protect air quality
- ☐ Transit eliminates the need to park or for destinations to provide parking
- ☐ Transit reduces traffic congestion
- ☐ *I do not think it is important to have transit service.*

20. How much do you agree with the following statements about funding transit? *Check one per row.*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I support using **city** funds for transit.	○	○	○	○	○
I support using **county** (or equivalent) funds for transit.	○	○	○	○	○
I support using **state** funds for transit.	○	○	○	○	○
I support using **federal** funds for transit.	○	○	○	○	○

21. Do you support more transit, less transit, or the same amount of transit in your community, given that public funds are needed to support part of the cost?

○ Less public transit ○ Same amount of public transit ○ More public transit

Most transit riders pay a fare to ride. The combined fares of all riders may or may not cover the entire cost of operating the service. In fact, most of the time transit services require some other sources of additional funds to pay for operations.

22. In general, how much of the total operating cost of transit should come from rider fares?

- ○ **All – 100%** (fares cover all costs)
- ○ **Most - >50%** (fares cover more than half of costs)
- ○ **Some - <50%** (fares cover less than half of costs)
- ○ **None – 0%** (no fare; other sources cover all costs)

23. Some transit riders pay a reduced fare.

Who should be eligible for reduced fare?

Check all that apply.

- ☐ Military veterans
- ☐ People with disabilities
- ☐ College/university students
- ☐ K-12 students
- ☐ Medicare or Medicaid cardholders
- ☐ Low-income individuals
- ☐ Other:

CONTINUE ON PAGE 5

We would like to understand how different situations would impact your choice to use or not use transit. We know from previous questions if you already use transit or not. So please answer the following question thinking about how each scenario may change your use of transit (or motivate you to begin using or stop using transit).

24. How would the following statements change your use of transit? *Check one per row.*

	Stop using transit	Use transit less often	No Change	Use transit more often	Begin using transit
Fuel prices increase to over $4.00 per gallon	○	○	○	○	○
Your car breaks down or is needed by someone else	○	○	○	○	○
Your household income decreases significantly	○	○	○	○	○
You are no longer able to drive for health reasons	○	○	○	○	○
You move to a more urban community with transit	○	○	○	○	○
You move to a more rural community with transit	○	○	○	○	○

Technology and Transportation in the Near Future

25. Assume you own a vehicle and smartphone…If you had to choose, which would you choose to give up permanently?

○ Vehicle (car/truck/motorcycle/scooter)

○ Smartphone (e.g., iPhone/Android)

In the future, you may not need to own a vehicle to have access to a vehicle when needed. For example, you may be able to join a subscription-based car-sharing service or use another mobility service of some type.

26. Which of the following statements most likely describes your future vehicle ownership?

○ *I do not own a vehicle now and I do not plan to get one in the future.*

○ I will no longer choose to own a vehicle in less than 1 year.

○ I will no longer choose to own a vehicle in 1 to 10 years.

○ I will no longer choose to own a vehicle in 11 to 20 years.

○ I will no longer choose to own a vehicle at some point beyond 20 years.

○ *I will always choose to own my own vehicle.*

Think about hourly or mileage based car-sharing services (e.g., Car2Go, CarShare, ZipCar) and assume they are available in your community now (if they are not already)…

27. How important is each factor in making car-sharing appealing and useful for you?

Check one per row.	Not important	Slightly important	Moderately important	Important	Very important
Variety in type of vehicle (car, van, truck, scooter)	○	○	○	○	○
Wheelchair accessible vehicles	○	○	○	○	○
Convenient vehicle location	○	○	○	○	○
Simple reservation process (internet, phone app)	○	○	○	○	○
Low monthly or annual membership fee	○	○	○	○	○
Low cost per mile/hour of service	○	○	○	○	○
Low daily maximum rate (for multi-day rentals)	○	○	○	○	○

Self-driving vehicles, called autonomous vehicles, will exist in the near future.

28. How comfortable are you with the idea of an autonomous vehicle picking up and dropping you off for a personal business appointment?

Very uncomfortable	Uncomfortable	Neutral	Comfortable	Very comfortable
○	○	○	○	○

CONTINUE ON BACK… ↘

Please answer all questions. Responses are confidential.

29. All things considered, how satisfied are you with your life as a whole these days?

Completely dissatisfied ← → Completely satisfied

0 1 2 3 4 5 6 7 8 9 10

30. In general, how would you rate your overall health? ○ Poor ○ Fair ○ Good

31. Are you? ○ Female ○ Male ○ Not listed:

32. What is your age?

- ○ 18 to 24 years
- ○ 25 to 34 years
- ○ 35 to 44 years
- ○ 45 to 54 years
- ○ 55 to 64 years
- ○ 65 to 74 years
- ○ 75 to 84 years
- ○ 85 or more years

33. What is the highest degree or level of school you have completed?

- ○ Some grade school (K-12)
- ○ High school graduate (diploma or GED)
- ○ Some college
- ○ Associate's degree
- ○ Bachelor's degree
- ○ Master's, professional, or doctorate degree

34. Are you of Hispanic, Latino, or Spanish origin? ○ Yes ○ No

35. What is your race? *Check all that apply.*

- ☐ White, Caucasian
- ☐ Black or African American
- ☐ American Indian or Alaska Native
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ Asian
- ☐ Some Other Race:

36. Including yourself, how many people live in your household? 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 or more ○

37. How many people in your household, including yourself and children, cannot drive? ○ 0 ○ 1 ○ 2 ○ 3 or more

38. Do you have a driver's license? ○ Yes ○ No

CONTINUE TOP OF NEXT COLUMN

39. How many working vehicles (cars, trucks, and motorcycles) are available in your household? 0 ○ 1 ○ 2 ○ 3 or more ○

40. Which of the following best describes your current employment status? *Check all that apply.*

- ☐ Employed full-time
- ☐ Employed part-time
- ☐ Student
- ☐ Homemaker
- ☐ Retired
- ☐ Unable to work due to a disability
- ☐ Not employed, looking for work
- ☐ Other:

41. What is the combined annual income for all people living in your household?

- ○ Less than $15,000
- ○ $15,000 to $24,999
- ○ $25,000 to $34,999
- ○ $35,000 to $49,999
- ○ $50,000 to $74,999
- ○ $75,000 to $99,999
- ○ $100,000 to $249,999
- ○ $250,000 or more

42. Have you served on active duty in the U.S. Armed Forces, Reserves, or National Guard?

○ No ○ Yes, previously ○ Yes, currently *Thank you for your service.*

43. Are you currently covered by either of the following programs? *Check one per row.*

Yes	No	
○	○	**Medicare** (age 65+ or Social Security Disability)
○	○	**Medicaid** (low income or people with disabilities)

44. Do you have serious difficulty walking or climbing stairs? ○ Yes ○ No

45. Do you use a wheelchair or other mobility assistive device to travel outside your residence? ○ Yes ○ No

CONTINUE ON PAGE 7 →

46. Please share any final comments you have regarding community livability or public transit:

Returning a **completed survey** means you are eligible to receive one $3.00 online gift card code.

Please indicate how you prefer to receive your gift card code by providing an SMS text capable mobile phone number or email address.

SMS text capable mobile phone number: *(xxx) xxx - xxxx*

Email address: *name@online.com*

Please write clearly and double-check your spelling. We will not re-send undeliverable or returned messages.

You will receive your code in the next four weeks.

Are you a current or former rider of public transit?

If NO... you are finished. Return all pages using the provided envelope.

If YES... please take 3 more minutes to answer a few questions about your use of transit...

A Few Questions for Transit Riders

47. How often do you ride public transit?

- ○ 6 or 7 days per week
- ○ 4 or 5 days per week
- ○ 2 or 3 days per week
- ○ 1 day per week
- ○ 1 or 2 days per month
- ○ Less than once per month
- ○ *I no longer ride transit.*

48. How much do you agree or disagree with the following statement?

"Public transit is very important to my quality-of-life."

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
○	○	○	○	○

49. How likely is it that you would recommend the public transit service you ride to a friend or colleague?

Not at all likely										Extremely Likely
0	1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○	○

50. Why did you start riding public transit? *Check all that apply.*

- ☐ I wanted to be more physically active.
- ☐ I enjoyed the social interaction of riding transit.
- ☐ I decided to use transit for convenience.
- ☐ I no longer had access to a vehicle.
- ☐ I decided to use transit to save money.
- ☐ I decided to use transit to reduce my energy consumption or protect air quality.
- ☐ I did not want to drive in poor weather (rainy, snowy).
- ☐ I could no longer drive or had difficulties driving.
- ☐ I could not get a ride from others or did not want to.
- ☐ I have a disability that limits my ability to travel other ways.
- ☐ I wanted to avoid congestion.
- ☐ I wanted to make better use of my time while traveling.
- ☐ Other reason(s):

CONTINUE ON BACK... ➘

About Your Most Recent Trip on Transit
Please answer the following questions about the most recent trip you took on transit.

51. If public transit had not been available, which one travel option would you have used to make the trip?
Check only the one option you would have used.

- ○ Drove my vehicle
- ○ Asked friend/family for a ride
- ○ Used church or service organization
- ○ Walked
- ○ Biked
- ○ Used bike-share
- ○ Used taxi-cab
- ○ Used ride-sourcing (e.g., Uber, Lyft)
- ○ Used car-share (e.g., Car2Go, ZipCar)
- ○ Used another travel option: _____
- ○ *I have no other travel options.*

52. When was your most recent trip on transit?

- ○ Today
- ○ Another day this week
- ○ Last week
- ○ 2 to 4 weeks ago
- ○ More than 4 weeks ago
- ○ *Not sure*

53. Which mode(s) of public transit did you use on the trip? *Check all that apply.*

- ☐ **Rail** (e.g., light rail, commuter rail, subway, etc.)
- ☐ **Local bus** (e.g., fixed, flexible, deviated, etc.)
- ☐ **Paratransit for people with disabilities**
- ☐ **Commuter bus** (e.g., express, park-and-ride, etc.)
- ☐ **Demand responsive transit** (e.g., dial-a-ride, etc.)
- ☐ **Intercity bus** (e.g., Greyhound, Megabus, etc.)
- ☐ **Vanpool**
- ☐ **Ferry**
- ☐ **Other mode(s)**: _____

54. What was the purpose for the trip?
Check all that apply.

- ☐ Work
- ☐ School, college, job training
- ☐ Medical appointments, health care, dental
- ☐ Family, personal business
- ☐ Social, recreational
- ☐ Shopping, errands
- ☐ Volunteering
- ☐ Other: _____

55. How much do you agree or disagree with the following statements? *Check one per row.*

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Does not apply
The vehicle arrived on-time.	○	○	○	○	○	○
The driver was helpful and friendly.	○	○	○	○	○	○
I felt safe riding transit.	○	○	○	○	○	○
The vehicle was clean.	○	○	○	○	○	○
The vehicle was comfortable.	○	○	○	○	○	○
The fare I paid was reasonable for my trip.	○	○	○	○	○	○

FINISHED!
RETURN ALL PAGES IN THE PROVIDED ENVELOPE.